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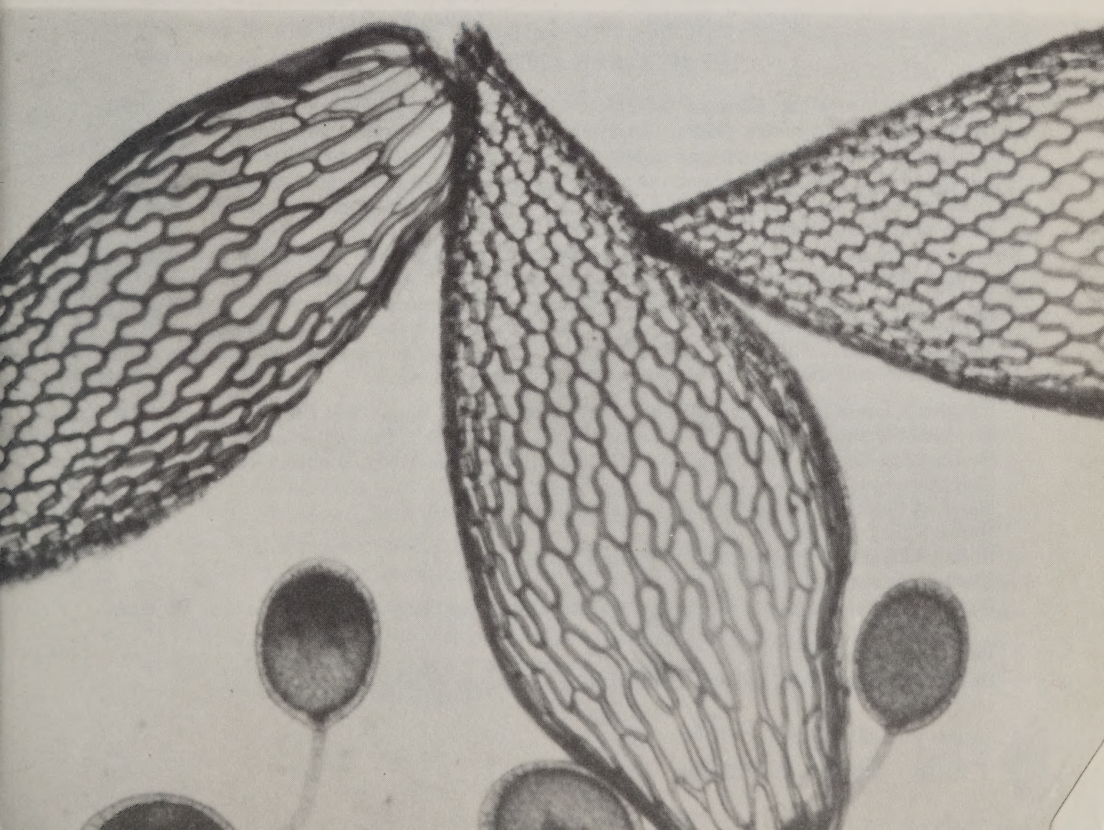
THE

MICHIGAN BOTANIST

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SUCCESSIONAL AND CLONAL CHANGES AT SITES
OF SMOOTH SUMAC (*RHUS GLABRA*) []

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Staghorn sumac (*Rhus typhina*) and smooth sumac (*R. glabra*) are early successional shrubs common throughout Michigan on upland rocky or sandy soils of disturbed habitats, including old fields, roadsides, and margins of woods. Sumac, like other woody plants such as aspen, sassafras, and dogwood, is clonal with many genetically identical stems arising from underground connections. Sumac clones are common along fence lines, with larger, presumably older stems in the middle and shorter, younger stems toward the periphery.

In 1958-59 Elizabeth Gilbert observed the phenology, structure, and development of nine smooth sumac clones (*Rhus glabra*) in northern Washtenaw County (Gilbert, 1961, 1966). The purpose of our study, conducted 22 years later at the same site, was to examine the current successional status of the site and to determine structural changes in the remaining clones.

The clones are located on a hill in the southeast corner of Stinchfield Woods (Washtenaw Co., T1S, R4E, sec. 14, SE 1/4). Land northeast of the study area was first settled in 1825, and by 1874 the study area was cleared and used for pasture (Gilbert, 1959). Ford Motor Company sold this area to the University of Michigan in 1949. According to Gilbert, in 1959, "Since 1949 or perhaps a few years earlier, the land has been idle, and the sumacs have almost completely taken over. A few volunteer trees, *Sassafras albidum* and *Prunus* sp., have become established." Before Gilbert's study the only disturbance to the area since the natural establishment of the sumacs was the construction of a road across the top of the hill in 1952. In 1962, the School of Natural Resources established a white pine (*Pinus strobus*) plantation displacing five of the nine clones (Fig. 1). Given the planting methods used at that time (Bruce Breitmeyer, pers. comm.), we are reasonably certain that two of the locations (Clones B and C) were disturbed only along their western borders and that the remaining two locations (Clones E and F) were relatively undisturbed. Clones E and F were located on the northern slope and Clones B and C on the top and southern slope of the hill. There is little protection by either topography or tall trees on the south and southeast. The northern slope is steeper than the southern, and it is somewhat protected by a nearby stand of tall hardwoods, as has been the case for over two decades (Gilbert, 1959). The area continues to be protected on the west by a hollow and another wooded hill of similar height. The original eastern side of the hill is missing, an abandoned county gravel pit being there since before the 1959 study. The soil is Bellefontaine sandy loam (Gilbert, 1959). Thus, this area is "typical" in history and site quality of many of the abandoned old fields of southeastern Michigan.

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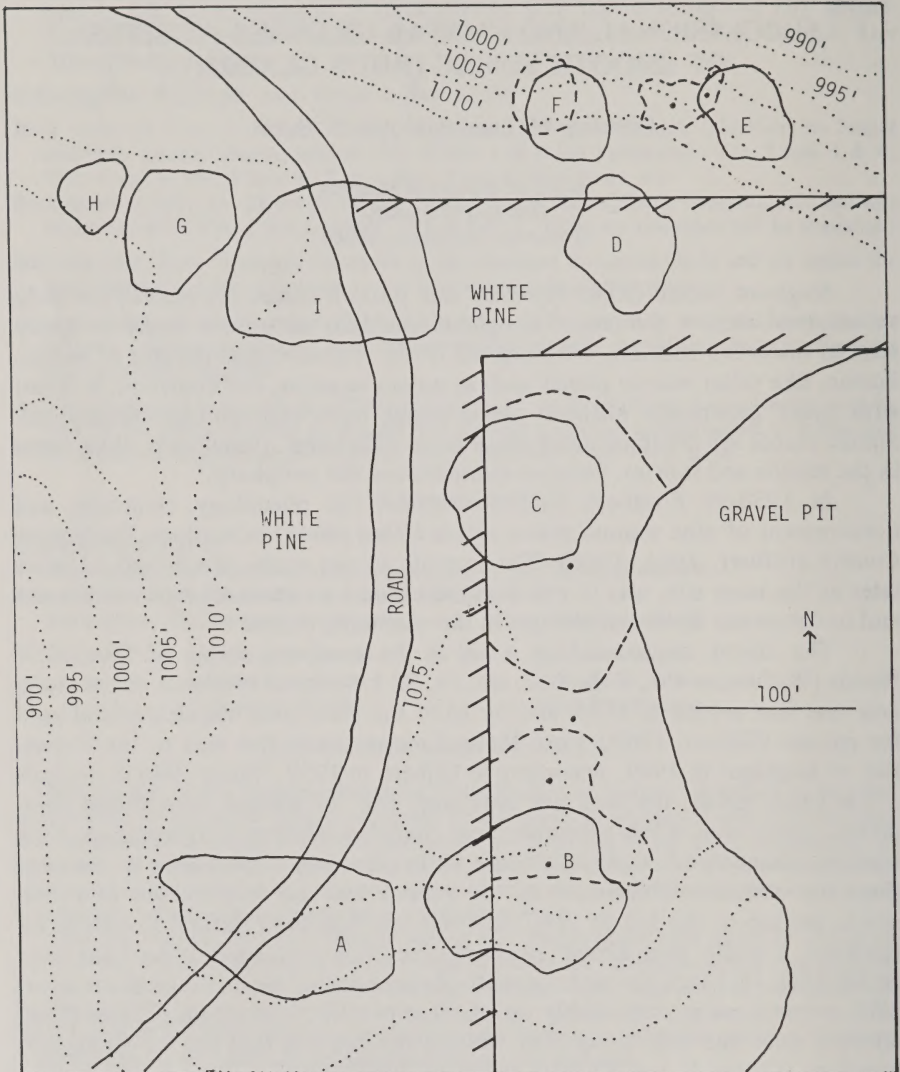


FIG. 1. Clone locations in 1959 and 1980. The 1958 locations and topographic features are from Gilbert (1959). Solid lines indicate Gilbert's (1959) clone locations. Dashed lines indicate 1980 clone locations. Large dots indicate stake locations.

Three factors were used to establish the identity of the clones: location, sex, and growth habit as determined by branching angle. Clone location was established by using the elevational line, the westernmost edge of the gravel pit, and the easternmost edge of the road as reference points, relative to Gilbert's (1959) map. The locations of our own permanent 4-foot metal reference stakes

are indicated in Figure 1. The shared border of Clones B and C was determined by the differences between the current clones in fruit color and the time of leaf fall in the autumn. No living sumac was present at Site F. If a smooth sumac clone was present, we noted the presence or absence of fruit and compared this to the sex of Gilbert's clones. Smooth sumac is described by Fernald (1950) as polygamous (with hermaphroditic or unisexual flowers on the same or on different individuals) or often dioecious. All clones observed (B, C, and E) had fruit and thus were consistent with the identification of these clones as female in 1959.

The growth pattern of smooth sumac allows determination of both a branching angle and the age of a stem. The inflorescence of sumac is terminal, and thus growth of the stem the next year is from a lateral bud below the inflorescence and at an angle relative to the last year's growth (the branching angle). The age of a stem can be determined by counting the greatest number of branching angles along one branch to the bottom of the stem. Most stems could be aged in this manner without radial growth of stems masking the older angles. Gilbert (1966) found significant differences in branching angles between clones and suggested that this could be used to characterize a given clone.

We measured 20 stems per clone, five randomly chosen from each quarter of a clone, and recorded all measurable angles down from a randomly chosen twig on each stem. Angles were measured to the nearest five degrees approximately 10 cm above the intersection forming the angle. We found no significant differences in branching angles for clones in the same location in 1959 and 1980 (Table 1). Thus, these results, as well as those used on location and sex, are consistent with the suggestion that the same clones may still persist in the same area after more than 20 years.

Once the location and identity of the clones had been established, we examined two factors to ascertain changes in the clones and successional status of each site: (1) the age distribution of stems as an indication of the current vigor of the clone; and (2) the numbers and identity of species invading the clones as a relative measure between clones of succession.

TABLE 1. Comparison between years of branching angles in clones. Branching angles in 1959 and 1980 for each clone were not significantly different from each other at the .05 level (Mann-Whitney U statistic).

Clone	Year	N	Angle (degrees) \bar{X} (S.D.)	P
B	1959	270	27.0 (13.3)	
B	1980	97	28.3 (9.0)	.09
C	1959	146	31.4 (12.6)	
C	1980	95	28.8 (9.2)	.15
E	1959	72	27.3 (9.7)	
E	1980	107	27.2 (7.8)	.68

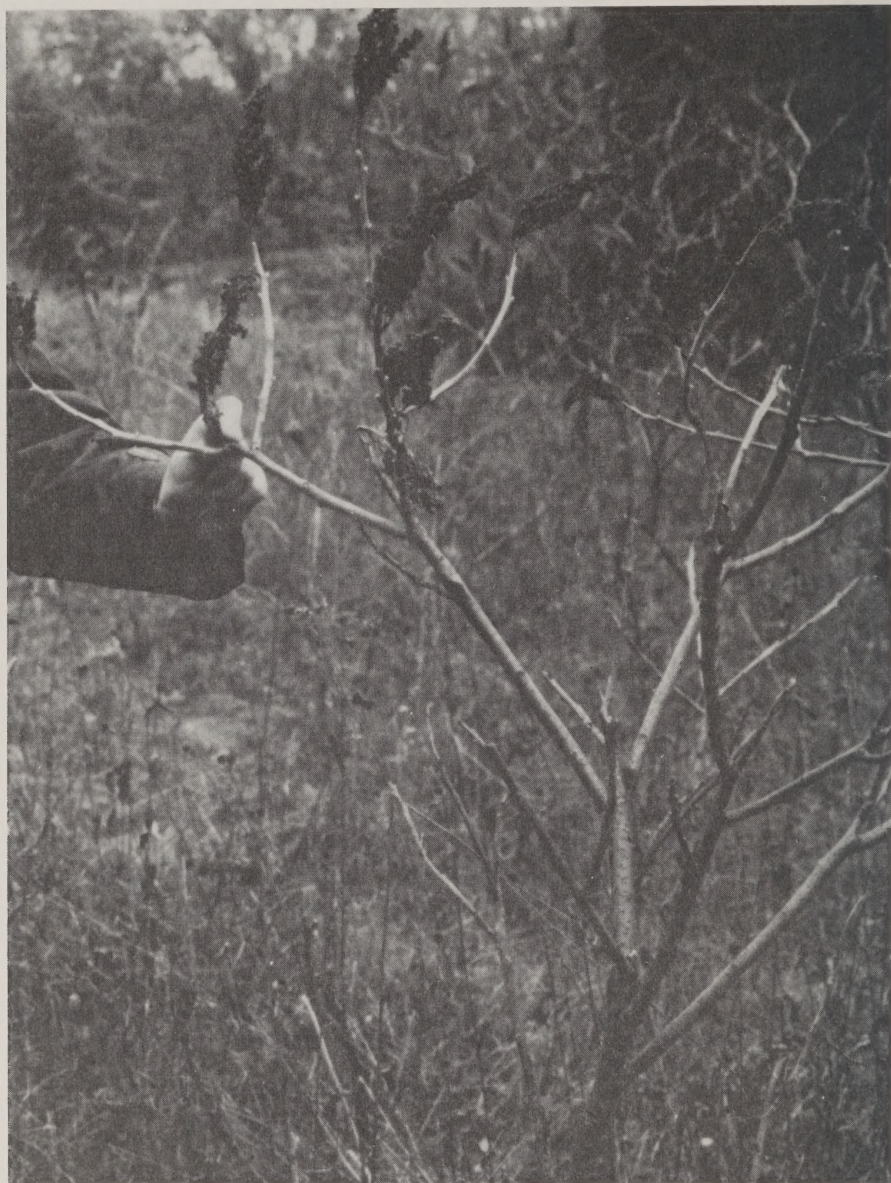


FIG. 2. *Rhus glabra* after leaf fall, showing terminal inflorescences and branching pattern.

Clones B and E were divided into quadrats (3×3 m in B, 2×2 m in E). Clone C was sampled using a belt transect of ten 4×4 m quadrats through the center of the clone in a north-south direction. The age of all sumac stems within

each quadrat was recorded. In addition, the number of stems of invading woody trees within the clone was recorded in one of three size classes (< 1 cm dbh, 1-5 cm dbh, > 5 cm dbh; dbh = diameter at breast height, or 4.5 feet). In location F, only the number and size of invading species in the 10×14 m area of the old clone were recorded.

From the age distribution of all stems measured (Table 2), it appears that the age of a clone (i.e., the number of years the same genotype is alive) may be much older than any of the extant above-ground stems. Only one of the 505 stems aged in 1980 was old enough to have been present at the time of Gilbert's

TABLE 2. Frequencies of age classes of stems in 1959 and 1980. Data from 1959 were samples from clones determined by location in clone, elevational gradient, and stem height (Gilbert, 1959). Data from 1980 are all stems present in Clones B and E and all stems within a 4×40 m north-south belt transect through Clone C.

AGE (yrs)	Number of Stems						
	Clone B		Clone C		Clone E		Clone F
	1959	1980	1959	1980	1959	1980	1959
1		59	2	11		18	
2		17	1	11		6	
3		43		7		7	
4	5	27	4	17	6	1	
5	6	19	7	23	3		6
6	10	24	6	28		3	8
7	15	30	5	20	11	4	7
8	12	9	7	7	7	6	6
9	3	3	1	1		3	8
10	6	9	7		3	7	2
11	4	5	3		1	5	2
12	1	15	4		1	6	
13		7	1	1	1	10	
14		4				4	
15	1	10				1	
16		4				3	
17		2				2	
18		2					
19		2					
20						1	
24		1					

study 22 years ago. The age of the clones in 1959 is not known, although the oldest stem in Gilbert's study was 15 years old. If sumac invaded soon after the land was idled (1949), the clones could now be more than 30 years old. Similarly, in other clonal woody plants, such as aspen, the same genotype has existed in one location for hundreds of years (Barnes, 1975).

The shape of the age distribution of stems for each clone also reveals the successional status of the clone. The median age of stems is four years in Clone B

exposed location on a north-facing slope, proximity to an oak-hickory woods, and lack of disturbance from the plantation. One- and two-year old stems are localized in the northwest and southeast corners of the clone only, and the median stem age (8 years) is much older than that of Clones B (4 years) and C (5 years). It is surrounded on all sides by other woody plants: white pine, sassafras, white oak (*Quercus alba*), false shagbark hickory (*Carya ovalis*), black oak, ground juniper, and cherry. The species found within the clone are larger and associated with later successional stages than those in Clones B and C, including white and black oak and false shagbark hickory (Table 3). In addition, black raspberry (*Rubus occidentalis*) is found throughout the clone, and grape vines cover the eastern half of the clone. Based on the older median age of the stems, size of surrounding vegetation, and quantity and identity of species within the clone, Clone E appears more advanced in succession, and its exclusion from the site within the next few years is likely.

Clone F was located in an area similar to that of E. No live sumac could be found in its location, although there were several large, dead sumac stems standing and fallen in the area. Although the area examined (10 × 14 m) was the smallest of the 4 clones, it had the largest number of different species (nine) and many larger later successional species: white and black oak, false shagbark, and flowering dogwood (*Cornus florida*). We believe that in this site the sumac has been excluded by later successional species.

In summary, it appears that after a 22-year period, one of the clones (F) died and was replaced by young oak-hickory forest. Another clone (E) is being actively invaded by grape, raspberry, and other early successional plants, as well as small oaks and hickories, and may well meet the same fate as Clone F. Two clones (B, C) are at an earlier stage of succession than E and F, larger in area and with relatively less invasion of their area by juniper, cherry, and sassafras. The difference in rates of succession between these areas is most likely a result of many factors. The relatively sheltered location, nearest to seed source, and lack of man-made disturbance have helped to hasten succession in the areas of Clone E and F. Sumac continues to thrive in the vicinity of clones B and C, partly because of disturbance to the area 18 years ago, but also perhaps because of the exposure and more distant seed sources.

We thank George J. Gamboa and R. Douglas Hunter for criticizing this paper, Michael Larch and Steven Briarton for field assistance, and the University of Michigan School of Natural Resources for the use of Stinchfield Woods. This study was supported in part by an undergraduate research grant from Oakland University to Christine Larch.

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GRIMMIA HERMANNII, NEW TO CANADA

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In 1974 I described from Michigan's Upper Peninsula a sterile *Grimmia* of modest size and undistinguished appearance made notable, however, by small, rounded, 1-4-celled gemmae produced in chains on axillary stalks. The moss was collected at Copper Harbor in Keweenaw County by Frederick J. Hermann, not far from his boyhood home, and it was named *Grimmia hermannii* in recognition of his important collecting activities in bryology. A number of other collections from the Upper Great Lakes region have come to hand, some already publicized in Crum & Anderson's *Mosses of Eastern North America*. They include additional collections from Keweenaw County, Michigan (at Agate and Eagle Harbors), as well as specimens from Minnesota (Lake Co.) and Wisconsin (Ashland, Marathon, Portage, Richland, and Sawyer Cos.). Dr. Hermann has also sent me a collection not previously recorded in the literature from Houghton Co., Michigan (in seepage on the face of a basaltic bluff in maple-birch woods on the slopes of Silver Mountain, 11 mi. N. of Sidnaw, no. 29001, June 22, 1981, MICH) and Iron Co., Wisconsin (on granite boulder at base of wooded bluff along U.S. Highway 51, 0.5 mi. S. of Hurley, no. 28396, June 28, 1978, MICH).

Some 20 years ago I examined a collection from the Rainy River District of Ontario (on surface of exposed rocky crest on The Ridge, along Highway 600, 8 mi. N. of Rainy River Town, Wildland Reserve, *Claude E. Garton* 8991, July 25, 1961, CAN, MICH). It is amusing to note that I considered it a probable new species and even wrote a preliminary description but completely forgot about it until eight years after describing the species from the Michigan locality.

Habitat data as given on labels are rarely very meaningful or reliable. It appears, however, that the species prefers hard, non-calcareous rock and grows in some degree of association with birch, maple, and aspen. The kinds of rock substrate include "granitic" (four collections), basalt (three collections), slate (one collection), and sandstone (one collection). Because the hyaline hair points on the leaves range from very short to fairly noticeable (though short), it can be inferred that the plants exist in shaded as well as exposed habitats.

Only female plants without sporophytes have been observed.

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RECENT WISCONSIN RECORDS FOR SOME INTERESTING
VASCULAR PLANTS IN THE WESTERN
GREAT LAKES REGION-II

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New distributional and ecological data are presented for six sedges new to Wisconsin or restricted in range in the state (*Carex concinna* R. Br., *C. exilis* Dewey, *C. lenticularis* Michx., *C. michauxiana* Boeckl., *Fuirena pumila* (Torr.) Spreng., *Rhynchospora fusca* (L.) Ait. f.). Distributions in the western Great Lakes region are mapped.

The status of several vascular plants of special interest in Wisconsin was recently presented on the basis of observations and collections (Tans & Read, 1975). New information has been collected for native species during coastal zone natural area inventory and floristic surveys with the Scientific Areas Section, Dept. of Natural Resources. In this paper, the status of six members of the Cyperaceae in the western Great Lakes region is presented, two of them not previously reported from Wisconsin. All the taxa are represented by specimens in the herbarium of the author unless otherwise cited. Standard herbarium designations of Holmgren & Keuken (1974) are used. Distribution maps were prepared from published records and field collections. Dots in Wisconsin and Minnesota represent actual locations; those in Michigan and Indiana merely represent counties of occurrence. Occurrences in Ontario were mapped from published records and specimens in MICH and WIS. (For some species, not all the known sites could be indicated due to proximity.)

Additional information on locations, population numbers, and habitat in Wisconsin would be welcomed by the Scientific Areas Section, where records of the status of critical plant species are maintained.

Carex concinna R. Br.

Fig. 1

Carex concinna ranges across northern North America from north-central Alaska to northernmost Ontario and southern Labrador, southward to Oregon, Colorado, South Dakota, Michigan, and southern Ontario (Scoggan, 1978). It is not known from Minnesota (Wheeler, pers. comm., 1977). Raymond (1951), who studied the distribution of sedges in Quebec, termed *C. concinna* a high-subarctic species, one that penetrates into arctic regions in a portion of its range.

This low and inconspicuous sedge has only recently been identified as a member of the Wisconsin flora. Zimmerman (1952) included *C. concinna* as probably occurring in Wisconsin. He was the first to collect *C. concinna* (3710, 1954, MIL, WIS); he noted its abundance on damp, limy beach ridges under white cedar and spruce in the Ridges Sanctuary, Door Co. Subsequent collections

(Bennett, 1957, F, MIN, WIS; Bennett 2590, 1961, F; Iltis 17556, WIS) from the Ridges Sanctuary confirmed the presence of sizable populations. In 1974, *C. concinna* was discovered about six miles from the Ridges at Pine Ledges (Marshall's Point, T31N, R28E). There low, somewhat dry, mossy ledges of Niagara dolomite provide a habitat suitable for plants of boreal affinities. *Carex concinna* grows there on ledges partly shaded by balsam fir, white cedar, and white spruce (Tans & Read, 1975). Field inspections for additional populations on the Door peninsula are certainly warranted, for there are comparable habitats nearby; the sedge probably has been overlooked, for it is inconspicuous. The calcareous nature of the bedrock and its proximity to the surface apparently provide a suitable substrate for *C. concinna*. Habitat descriptions in nearly all floras (e.g., Hermann, 1970; Voss, 1972; Scoggan, 1978) mention its occurrence in calcareous areas. In addition, the cool, humid climate of coastal Door County, considerably moderated by Lake Michigan, is similar in many respects to that of regions far to the north where this sedge is more frequent. A third *Carex concinna* population represents a significant disjunction within Wisconsin. It is located in a disturbed (brushed) site on the north side of Devil's Island (the northernmost island of the Apostle Island archipelago) near the lighthouse. The species occurs with *Abies balsamea*, *Ledum groenlandicum*, *Alnus crispa*, *Carex peckii*, *C. capillaris*, *C. aurea*, *C. castanea*, and *C. deflexa* (Tans 1612, 1977), in Ashland County, T53N, R3W, Sect. 10. The site is on the nearly level upland surface only several meters back from vertical sandstone cliffs above Lake Superior, here carved into spectacular arches, deep caves, and undercut ledges. On these same cliffs occur *Pinguicula vulgaris* (Butterwort), restricted in Wisconsin to this and one other north-facing cliff in the Apostle Islands; *Carex lenticularis*, known from three sites in the state, two on the Apostle Islands; and *Primula mistassinica* (Arctic Primrose), restricted in Wisconsin to a few cliffs in or near the "Driftless Area" and portions of the shores of the Great Lakes (Iltis & Shaughnessy, 1960; Soper et al., 1965).

Carex exilis Dewey

Fig. 2

Carex exilis, a low-subarctic species (Raymond, 1951), ranges from Delaware to central Labrador along the Atlantic coast, inland through New York to western Ontario and northern Minnesota, and across most of Ontario and Quebec (Reznicek & Ball, 1980). This sedge has been reported from as far south as North Carolina (Fox et al., 1950; Radford et al., 1968) and southern Mississippi (Reznicek & Ball, 1980). In Wisconsin, it is near its western range limit.

This member of the Stellulatae group, which in Wisconsin includes *Carex interior*, *C. angustior*, *C. cephalantha*, and *C. sterilis*, all inhabitants of northern *Sphagnum* bogs or southeastern Wisconsin calcareous fens, is distinctive in possessing a single, terminal spike. A sight record for *Carex exilis* was reported by Dr. James H. Zimmerman (pers. comm., 1977) from Door Co., T28N, R27E, Sect. 16 & 21, July 3, 1977, northeast corner of Schmoke Lake, in tussocks on a floating, calcareous bog mat. It is documented for the first time in Wisconsin with two collections from the Apostle Islands: (1) Big Bay bog in Big Bay State Park, Madeline Island, Ashland Co., T45N, R3W, NW¼ Sect. 24, Aug. 10, 1974;

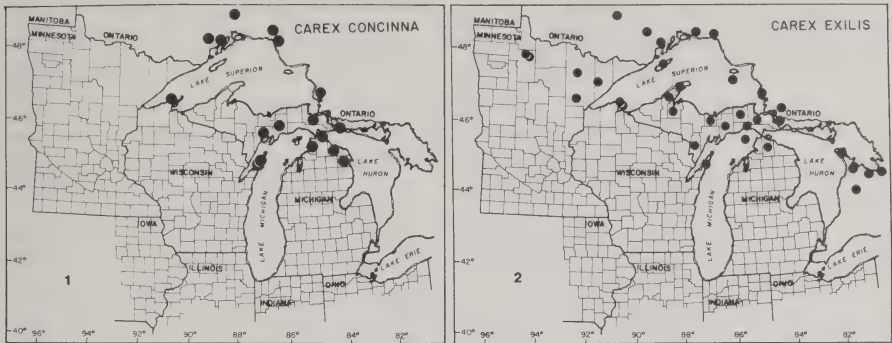


Fig. 1. *Carex concinna* in the western Great Lakes region. Fig. 2. *Carex exilis* in the western Great Lakes region.—Dots indicate actual locations in Minnesota and Wisconsin and counties of occurrence in Michigan.

a dominant sedge of open *Sphagnum* bog in association with *Eriophorum tenellum*, *Habenaria lacera*, *Rhynchospora fusca*, *Utricularia cornuta*, and *Xyris montana* (Tans 925, WIS). (2) Stockton Island, Ashland Co., T25N, R2W, SE¼, Sect. 36, Aug. 4, 1977; in *Sphagnum* bog and rear dune beach pool, in 1-2 dm of water over sand, associated with *Brasenia schreberi*, *Cladium mariscoides*, *Eleocharis robbinsii*, and *Eriocaulon septangulare* (Tans 1654). The bicentric distribution at the northwest (Lake Superior south shore) and northeast tips (Door peninsula) of the state is unusual, though shared by several other species. These include *Carex capillaris*, a widespread, circumpolar species (Hultén, 1968); *C. concinna*, a transcontinental American boreal species; *Osmorhiza chilensis*, widespread in the western cordillera with disjunct populations in the Great Lakes region and northeastward to Labrador in North America (Gleason & Cronquist, 1963; Constance & Shan, 1948); and *Botrychium lunaria*, widespread in northeastern and western North America and Eurasia (Wherry, 1972; Peck & Taylor, 1980). The restriction of many other species, to one or the other of these peninsulas make these areas particularly attractive to further botanical analysis.

Carex lenticularis Michx.

Fig. 3

Carex lenticularis is a transcontinental species of northern North America, very similar in distribution to *C. concinna*, and found in Wisconsin at the southern edge of its Midwest range. It is known from central British Columbia to Newfoundland, south to California, Idaho, Montana, Minnesota, Michigan, and Massachusetts (Scoggan, 1978; Hermann, 1970).

Although frequent in the Lake Superior regions of Minnesota and Michigan, this handsome and distinctive boreal sedge has seldom been encountered in Wisconsin. Initially collected along the Lake Michigan shore at Two Rivers, Manitowoc Co. (*E. Dapprich* 7946, MIL, not dated, but near the turn of the century?), it has not been seen there again. Zimmerman (1952) included *C.*

lenticularis as a probable Wisconsin species but saw only Dapprich's collection. Three recent collections have established this sedge as a component of our flora: (1) Devil's Island, Apostle Islands, Ashland Co., T53N, R3W, Sect. 10, June 13, 1977, plant rare, tufted, on a west-facing, sandstone ledge 2.5 m above Lake Superior, associated with *Solidago graminifolia* and *Primula mistassinica* in an area moistened by seepage (*Tans* 1603, WIS) (2) Stockton Island, Apostle Islands, Ashland Co., T52N, R2W, Sect. 36, Aug. 4, 1977, rare, caespitose, on wet sand of rear dune beach pool with *Cladium mariscoides*, *Carex viridula*, *Utricularia cornuta*, *Eriocaulon septangulare*, and *Rhynchospora fusca* (*Tans* 1657). Barbara Coffin (University of Minnesota) was the first to collect it from this site while investigating the formation and geological history of the Stockton Island beach ridges. (3) Sandy, gravelly, north shore of Big Muskellunge Lake, Vilas Co., T41N, R7E, June 28, 1978 (*Iltis* 28,358, WIS).

Carex lenticularis may be more frequent in our area than records indicate, for sedges are avoided by most plant collectors, and accurate determination depends on having fertile material. Since the spikelets of *Carex lenticularis* disarticulate by midsummer, the duration for recognizing this plant in the wild is at most about two months. Areas along Lake Superior (e.g., Long Island-Chequamegon Point; Bark Bay, Siskiwit Bay, and Big Bay sand spits; Wisconsin Point) with moist beach sands and little vegetative competition, as well as sandy shores of inland lakes in northern Wisconsin, are potential sites for *Carex lenticularis* populations and merit field investigation during June and July.

Carex michauxiana Boeckl.

Fig. 4

The range of *Carex michauxiana* has been described as Ontario, at the north shore of Lake Superior, to Quebec (Lake Mistassini and Côte-Nord), southern Labrador, Newfoundland, New Brunswick, and Nova Scotia, south to

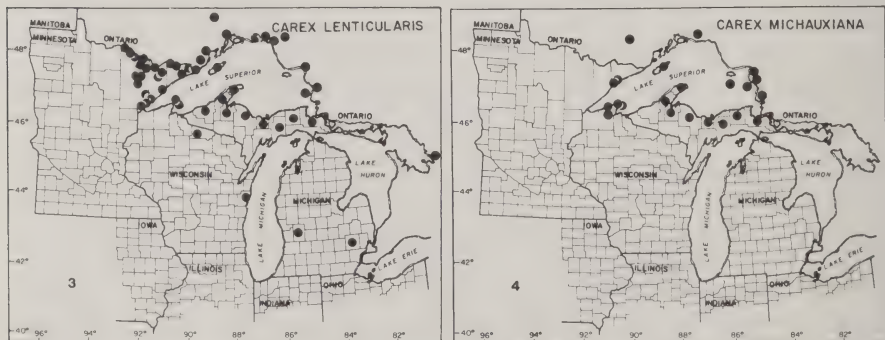


Fig. 3. *Carex lenticularis* in the western Great Lakes region. (The records for the three southernmost locations in Wisconsin and Michigan are old and may be useful only in indicating the past range.) Fig. 4. *Carex michauxiana* in the western Great Lakes region.—Dots indicate actual locations in Minnesota and Wisconsin and counties of occurrence in Michigan.

northern Michigan and western Massachusetts; also Asia (Scoggan, 1978). The species has also been reported from northern Saskatchewan by Argus (1968) and Harms et al. (1980), apparently disjunct from the western Great Lakes region.

This low-subarctic (Raymond, 1951) sedge has been known from Wisconsin since 1917 when it was collected from the Stockton Island bog by Charles Goessl. Several collections in the last 10 years have reaffirmed its presence there in the large, undisturbed *Sphagnum* and sedge bog. Tans & Read (1975) discovered the first mainland populations at Raspberry Bay bog, T51N, R4W, Sect. 2, Bayfield Co., near the mouth of the Raspberry River at Lake Superior. Despite intensive field investigations in all of the major Lake Superior mainland coastal bogs, as well as those in the outlying Apostle Islands, only one additional coastal site for *C. michauxiana* has been found: At Bark Bay, Bayfield Co., T51N, R7W, Sect. 35, *C. michauxiana* occurs in an open, wet *Carex lasiocarpa* and *Sphagnum* bog in association with *Andromeda glaucophylla*, *Carex chordorrhiza*, *C. limosa*, and *C. paupercula* (Tans 1350). At Bark Bay, as in the other two large bogs, substantial populations are present. In 1981 the first inland population was discovered about 13 miles south of Bark Bay on the shores of Sunken Camp Lakes (Solheim, WIS).

Fuirena pumila (Torr.) Spreng. (*F. squarrosa* of many authors)

Fig. 5

The main range of *Fuirena pumila* is near the coast from Massachusetts southward through the coastal plain to southern peninsular Florida and west in the Gulf plain to southern Texas, with disjunct populations inland in southern Michigan and northern Indiana (Kral, 1978). Fernald (1950) and Jones (1963) included northeastern Illinois in the range, but Mohlenbrock & Ladd (1978) did not include the species for Illinois, nor did Braun (1967) for Ohio. Swink & Wilhelm (1979) cited Porter Co., Indiana, in the Chicago region where it formerly occurred, that station now destroyed by development. Deam (1940) mapped Steuben Co., Indiana, in addition to Porter Co.

This annual member of the sedge family, reported here for the first time from Wisconsin, was collected in Marquette Co., T16N, R9E, Sect. 7, where it was common on wet, sandy shore and mud flats of Silver Lake, Aug. 9, 1977 (Tans 1669, WIS) and Aug. 21 (Tans 1676). Because of a severe drought during 1976, the shores of this seepage lake receded drastically, leaving a large mud flat with shallow pools and a wide, sandy shore. The well-developed shore and mud flat flora at Silver Lake included a remarkable association of species, some rare, local, or otherwise interesting, including *Fimbristylis autumnalis*, *Hypericum major*, *H. boreale*, *Juncus canadensis*, *Leersia oryzoides*, *Psilocarya scirpoides*, *Scirpus smithii*, *Triadenum fraseri*, and *Utricularia gibba*. Unusual emergent aquatics were *Eleocharis robbinsii*, *Eriocaulon septangulare*, and *Scirpus subterminalis*. On the drier, sandy shores were *Rhexia virginica*, *Rhynchospora capitellata*, and *Xyris torta*.

This report of *Fuirena pumila* from central Wisconsin is most remarkable, for not only is it new for the state, but it extends the known range of the species some 320 km from northern Indiana. This record is not totally surprising,

however, in view of the wide range of the species and the similarity between the sand regions in central Wisconsin and those along the coastal plain. A number of Atlantic coastal plain species disjunct in central Wisconsin, at Silver Lake or nearby, include *Scleria reticularis* (Hartley, 1959), *Psilocarya scirpoides* (Greene, 1953), and *Xyris torta* (Fassett, 1932; McLaughlin, 1932), which also occurs on the outwash sands of northwestern Wisconsin. Other species in our flora with coastal plain affinities are too numerous to list here (Peattie, 1922; Fernald, 1942).

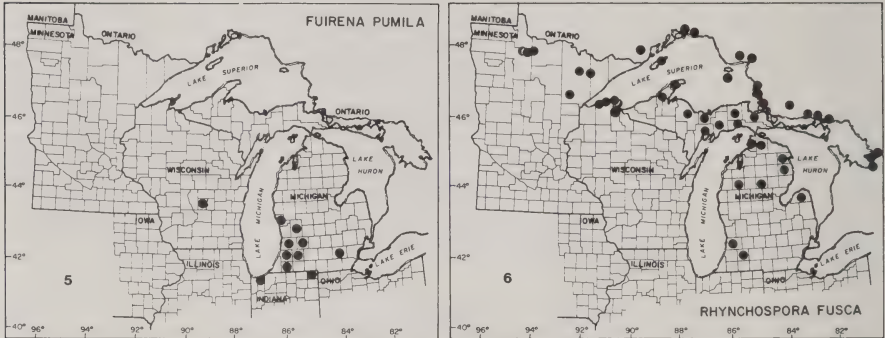


Fig. 5. *Fuirena pumila* in the western Great Lakes region. Fig. 6. *Rhynchospora fusca* in the western Great Lakes region.—Dots indicate actual locations in Minnesota and Wisconsin and counties of occurrence in Michigan and Indiana. Not all adjacent locations in Minnesota and Wisconsin could be mapped.

Rhynchospora fusca (L.) Ait. f.

Fig. 6

In temperate eastern North America, *Rhynchospora fusca* ranges from Newfoundland to Ontario and south to New England, New York, Delaware, and Michigan (Fernald, 1950). Gleason & Cronquist (1963) supplemented this statement of range as "around the Great Lakes," but did not specifically mention Wisconsin or Minnesota. A number of years ago Lakela (1951) reported this species of Beak-rush from northeastern Minnesota, and Gale (1944, map 24) mapped its distribution along the shores of Lakes Huron, Michigan, and Superior. More recently, Wheeler & Glaser (1979) discovered several populations in the Red Lake peatlands of northern Minnesota, and Harms et al. (1980) reported it from northwestern Saskatchewan, the westernmost station in North America. Hultén (1958, map 37) showed the distribution of this amphi-Atlantic (or Europeo-American) species.

Rhynchospora fusca, a typical boreal plant, was reported from Wisconsin by Greene (1953), based on an old specimen of L. S. Cheney (7118, WIS) from the south shore of Lake Superior near Port Wing. For nearly a century this has been the only known collection from the state. Between 1974 and 1978, 10 new stations were discovered, and Cheney's original population was also verified

as extant. *Rhynchospora fusca* occurs in open *Sphagnum* or sedge bogs, on the edges of bog pools or on open, wet sands in many of the coastal bogs. Such bogs on the mainland (e.g., Bark Bay, Siskiwit Bay, Honest John Lake, and Raspberry Bay) and in the Apostle Islands (e.g., Madeline, Stockton, Outer, and Michigan Islands) have apparently remained virtually unchanged since white settlement and have thus retained their complement of "critical" plant species.

Appreciation is extended to Edward G. Voss and A. A. Reznicek, Univ. of Michigan, for providing distributional records in Michigan and Ontario; Gerald B. Ownbey and Gerald A. Wheeler, Univ. of Minnesota, for range maps and recent records in Minnesota; Hugh H. Iltis, Univ. of Wisconsin, for access to herbarium records and literature; James H. Zimmerman for verifying *Carex* specimens and reviewing the manuscript; and U. S. Park Service, Apostle Islands National Lakeshore personnel for providing transportation to some of the remote Apostle Islands. Robert H. Read, Bil Alverson, and Theodore Cochrane reviewed the manuscript and provided many helpful suggestions.

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ELEOCHARIS ROSTELLATA AND ITS RELATION TO SPRING FENS IN MINNESOTA¹

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A small population of *Eleocharis rostellata* Torr. was discovered on August 12, 1980 in a spring fen (sensu Tarnocai 1974) on the Nett Lake Indian Reservation in northern Minnesota. This species has not been previously reported for Minnesota, and no records of occurrence in the state exist in the University of Minnesota Herbarium. *Eleocharis rostellata* is widely distributed across North America, but a significant gap in its range occurs across the northern Great Plains from eastern Wisconsin and Ontario to the Rocky Mountains and southward to extreme southwestern South Dakota (Svenson 1934, 1957; Fernald 1970; Cronquist et al. 1977; McGregor & Barkley 1977; Scoggan 1978). It is common in salt marshes along the Atlantic coast and extends inland in highly calcareous or alkaline situations.

In Minnesota, the species is restricted to a single transverse peat ridge in a narrow, sinuous water track bearing highly calcareous water (Fig. 1). This track is part of a network of open channels that dissect a minerotrophic swamp forest at the southern margin of Nett Lake. The waters in this track have a white, marly precipitate on the surface and an exceptionally high pH (7.21) and Ca^{2+} concentration (87 mg L⁻¹). The water tracks apparently arose by paludification of the swamp forest, because several peat cores indicate that the uppermost 70 cm of fen peat overlie a dense wood layer with *Sphagnum*. The peat depth varies from 2.5 m in the track to 3 m in the adjacent forest.

The vegetation associated with *E. rostellata* in this stand was described with a 10 × 10 m relevé plot (Shimwell 1971; Westhoff & van der Maarel 1973), presented in Table 1. The most significant species found in the plot and the adjacent water track is *Cladium mariscoides*, a rare species in Minnesota consistently occurring in spring fens, together with *Scirpus cespitosus* var. *callosus* and *Carex livida* var. *grayana*, which are generally restricted to patterned fens in northern Minnesota inland from Lake Superior.

The range of *Eleocharis rostellata* may be greatly extended by surveys of other spring fens in the Glacial Lake Agassiz peatlands of Minnesota and neighboring Manitoba. However, no other stations for this species were discovered at three other spring fens in northern Minnesota of a striking similarity in vegetation, water chemistry, and landform pattern. The presence of highly calcareous waters, moreover, may not be the sole requirement for *E. rostellata*, because this species has not been discovered in a series of highly calcareous prairie fens of northwestern and southern Minnesota investigated by Welby Smith of the

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FIG. 1. Aerial photograph of the Nett Lake Fen where *Eleocharis rostellata* was collected in the narrow water track indicated by the arrow. The photograph covers an area of approximately 2.5 km².

Minnesota Dept. of Natural Resources. The discovery of *E. rostellata* in only one station in northern Minnesota is thus remarkable owing to what appears to be a much wider distribution of suitable habitat.

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TABLE 1. Relevé of the *Eleocharis rostellata* stand. Relevé number 86. Location NE¼ NE¼ Sec. 33, T56N, R22W. Vegetation cover 100%. Height above water table 10 cm.

<i>Eleocharis rostellata</i>	1.2	<i>Carex limosa</i>	1.2
<i>Scirpus cespitosus</i> var. <i>callosus</i>	4.4	<i>Phragmites communis</i>	1.2
<i>Rhynchospora alba</i>	1.2	<i>Carex diandra</i>	1.2

Additional species in relevé: *Lobelia kalmii*, +.2; *Sarracenia purpurea*, +.1; *Andromeda glaucophylla*, +.2; *Parnassia palustris*, +.2; *Typha latifolia*, +.1; *Menyanthes trifoliata*, +.1; *Betula pumila* var. *glandulifera*, +.2; *Thuja occidentalis*, +.1; *Cladium mariscoides*, +.1; *Eleocharis compressa*, +.1; *Triglochin maritima*, +.1; *Utricularia intermedia*, +.1; *Larix laricina*, +.1; *Ledum groenlandicum*, +.2; *Picea mariana*, +.1; *Vaccinium vitis-idaea*, +.1; *Rhamnus alnifolia*, +.1; *Vaccinium oxycoccos*, +.1; *Drosera rotundifolia*, +.1; *Vaccinium myrtilloides*, +.1; *Aster junciformis*, +.1.

Bryophytes collected but not assigned cover values: *Fissidens osmundioides*, *Campylium chrysophyllum*, *Drepanocladus revolvens*, *Polytrichum juniperinum* var. *affine*, *Pleurozium schreberi*, *Sphagnum fuscum*.

The symbols after each species stand for cover and sociability, respectively. *Cover*: +, sparsely present; 1, plentiful but small cover value, 4, any number of individuals covering ½ to ¾ area. *Sociability*: 1, growing singly, as isolated individuals; 2, grouped or tufted; 4, in small colonies, extensive patches, or carpets.

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CAREX EXILIS AND SCIRPUS CESPITOSUS VAR. CALLOSUS IN PATTERNED FENS IN NORTHERN MINNESOTA¹

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The known Minnesota distribution of *Carex exilis* Dew. and *Scirpus cespitosus* var. *callosus* Bigel. has been recently extended across the extensive peatlands of Glacial Lakes Agassiz, Aitken, and Upham. *Carex exilis* was first reported in Minnesota from the Red Lake Peatland (Wheeler & Glaser 1979), where it reaches its western range limit in North America; four additional stations are reported here (Fig. 1). *Scirpus cespitosus* var. *callosus* generally occurs with *Carex exilis* in Minnesota but has a much wider distribution in the state. *Scirpus cespitosus*, long known from the north shore of Lake Superior (Roberts 1880; Juni 1879; Cheney 1893; Butters & Abbe 1953), was collected by C. O. Rosendahl in a marl fen in southwestern Minnesota in 1929. *Scirpus cespitosus* was first collected in a northern Minnesota peatland by Wheeler and Glaser at Red Lake; 15 additional stations across northern Minnesota are presented in Fig. 2.

Carex exilis and *Scirpus cespitosus* grow in a wide range of peatland sites in northern Minnesota, ranging from poor to extremely rich fens (pH 4.8-7.2; Ca^{2+} concentration: 0.9-87.0 mg L⁻¹; specific conductivity K_{corr} 43.8-148.2 $\mu\text{S cm}^{-1}$). They are often dominant partially as a result of a strongly cespitose habit. They are most often associated with *Rhynchospora alba*, *Carex lasiocarpa*, *C. livida*, *Sarracenia purpurea*, *Andromeda glaucophylla*, and *Menyanthes trifoliata*. Rare plants that occur at these sites are *Drosera anglica*, *D. linearis*, *Rhynchospora fusca*, *Xyris montana*, and *Cladium mariscoides*. *Carex exilis* and *Scirpus cespitosus* are restricted to two types of patterned peatland in northern Minnesota: patterned fens with regular networks of sinuous peat ridges (strings) and pools (flarks) oriented perpendicular to the slope and spring fens with anastomosing networks of open channels dissecting a dense swamp forest. At Red Lake these two species are most abundant around the margins of ovoid bog islands, where they grow out into the adjacent tracks along linear peat ridges (Glaser et al. 1981). Elsewhere at Red Lake and in northern Minnesota the two species often grow in drier pools in which clones of *Rhynchospora alba* or *R. fusca* occur with circular hummocks composed of *Sphagnum magellanicum*, *S. fuscum*, and *S. rubellum*. In the richest fens, however, *Scirpus cespitosus* and *Carex exilis* do not attain high cover values but are either highly localized or scattered. They are found in Minnesota on decomposing sedge peat or occasionally carpets of *Sphagnum*.

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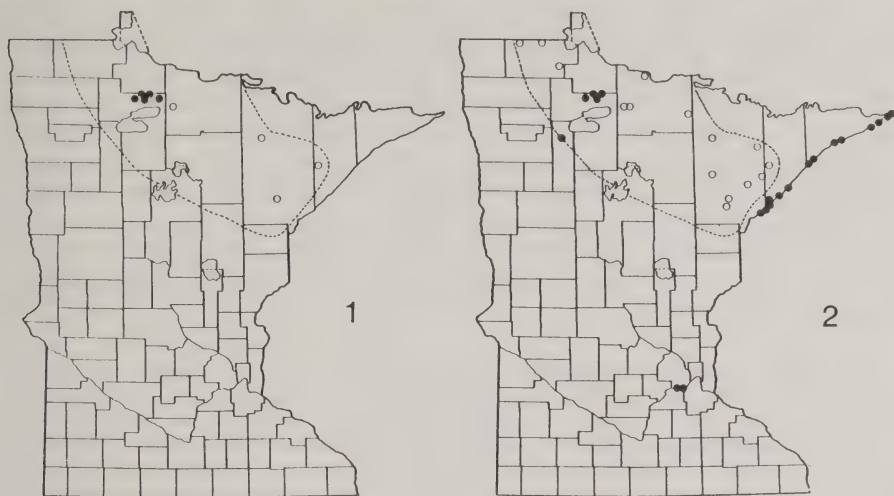


FIG. 1. The distribution of *Carex exilis* in Minnesota. Previously known stations from the Red Lake Peatland are indicated by black dots; white dots represent new stations. FIG. 2. The distribution of *Scirpus cespitosus* var. *callosus* in Minnesota. Previously reported stations from the north shore of Lake Superior, Red Lake Peatland, and southern Minnesota are marked by black dots. White dots indicate new stations. (The limit of patterned peatlands is shown by the dotted line.)

The most striking feature of the Minnesota distribution of these species is their restriction to minerotrophic fens, in contrast to a dominant role in acid ombrotrophic bogs in maritime districts of eastern Canada and northern Maine. *Scirpus cespitosus* is the more common dominant in moist ombrotrophic lawn communities, whereas *Carex exilis* is more abundant in wetter lawns, on mud bottoms, and around pool margins (Osvald 1970; Damman 1977, 1980). In Minnesota open lawns are dominated by *Carex oligosperma* bogs and are prone to dry out to a depth of 50-30 cm in dry summers; drying may help to exclude *Carex exilis* and *Scirpus cespitosus* from such areas. However, *Carex exilis* is also absent from raised bogs in the Hudson Bay Lowlands (Sjörs 1963) and southeastern Labrador, where bog pools, wet lawns, and mud-bottom communities are a prominent feature.

The displacement of mire species along nutrient gradients from maritime to continental bogs is a common phenomenon of peatlands in North America (Damman 1980) and Europe (Du Rietz 1947; Gorham 1956; Moore & Bellamy 1974). This behavior is especially puzzling, because many mire species have such a high fidelity for certain narrow ranges of water chemistry that they may be considered good ecological indicators within a given geographic region (Sjörs 1963). Possible explanations offered for the presence of continental fen species in maritime bogs are greater nutrient availability in maritime regions because of the entrainment of ocean spray in on-shore winds (Pearsall & Lind 1941; Witting 1947; Gorham 1956); greater flushing of H^+ and SO_4^- ions in maritime

bogs because of higher precipitation (Bellamy & Bellamy 1967); and greater climatic stress in continental bogs creating differing sensitivity among species to low nutrient levels (Gorham 1957; Gore 1963; Goodman & Perkins 1968). In Minnesota the more restricted occurrence of *Carex exilis* relative to *Scirpus cespitosus* in what appear to be similar habitats with closely comparable species assemblages suggests that genetic factors are important determining the distributions. Competitive interactions between species seem less likely to account for the absence of *Carex exilis* and *Scirpus cespitosus* from raised bogs in Minnesota, because the Minnesota bog flora is composed essentially of only a small fraction of the species common to maritime bogs in eastern North America.

Scirpus cespitosus var. *callosus*—LAKE CO.: 3 mi. NE of Greenwood Lake, NE¼ SE¼ Sec. 34, T59N, R11W, 1146. ST. LOUIS CO.: 5 mi. NW of Brinson, SE¼ NW¼ Sec. 8, T56N, R12W, 1110. 2 mi. SW of Markham, NE¼ Sec. 4, T55N, R12W, 1135. 7 mi. W of Forbes, SE¼ SE¼ Sec. 33, T57N, R19W, 1133. 1½ mi. E of Nichols Lake, SW¼ NE¼ Sec. 16, T53N, R17W, 1123. 10 mi. E of Babbet, SE¼ SE¼ Sec. 13, T60N, R12W, 1102. 2½ mi. N of Alborn, NW¼ NW¼ Sec. 12, T52N, R18W, 1058. 5 mi. W of Tower, SW¼ NE¼ Sec. 6, T61N, R16W, 1133. ROSEAU CO.: 16 mi. S of Warroad, NE¼ NE¼ Sec. 15, T160N, R37W, 1369. 2 mi. NE of Pine Creek, NE¼ SE¼ Sec. 25, T164N, R41W, 1262. 14 mi. NW of Badger, T164N, R43W, Sec. 36, 1385. KOCHICHING CO.: 11 mi. W of Loman, NE¼ NW¼ Sec. 25, T159N, R26W, 1213. 8 mi. E of Washish airport, SW¼ NW¼ Sec. 14, T154N, R29W, 1377. 8 mi. NE of Waskish airport, NW¼ SE¼ Sec. 35, T155N, R29W, 1416. 6 mi. N of Silverdale, SE¼ NE¼ Sec. 33, T65N, R22W, 1504.

Carex exilis—LAKE CO.: 3 mi. NW of Greenwood Lake, NE¼ SE¼ Sec. 34, T59N, R11W, 1142. ST. LOUIS CO.: 2½ mi. N of Alborn, NW¼ NW¼ Sec. 12, T52N, R18W, 1055. 5 mi. W of Tower, SW¼ NE¼ Sec. 6 T61N, R16W, 1092.

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A RANGE EXTENSION OF *SCLERIA VERTICILLATA* IN MINNESOTA¹

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Scleria verticillata Muhl. (Low Nut Rush) is an annual species of calcareous wetlands, ranging from Minnesota to Connecticut and south to Florida and Texas. Although relatively wide-ranging, its distribution is local and sporadic (Fernald, 1950). In fact, it is quite rare in the Upper Midwest where it reaches the northwest edge of its range. It is presumed to be extinct in Iowa (Roosa & Eilers, 1978) and is on the unofficial "watch list" in Wisconsin (1982). In Minnesota, it is being considered by the Endangered Species Technical Advisory Committee for listing in the recently amended endangered species legislation (Minn. Statutes, 1980, sect. 97.488). It has not been reported from South Dakota (Van Bruggen, 1976), North Dakota (Stevens, 1950), or portions of Canada north of 45° lat. (Scoggan, 1978).

Previously, the most northwestern stations known were in the Minnesota River Valley in east-central Minnesota. During 1981 floristic studies in northwestern Minnesota resulted in the discovery of three populations in Clay, Becker, and Norman Counties. They extend the known range of this species approximately 225 miles. The new populations are well within the Great Plains Floristic Province, where the species has not previously been reported (McGregor & Barkley, 1977).

An additional population was discovered in 1981 in southwestern Minnesota, in Jackson Co. in the Des Moines River Valley. This discovery is especially noteworthy because the only population of *S. verticillata* reported from Iowa was also located in the Des Moines River Valley approximately 30 miles southeast of the Jackson Co. population. The Iowa population was destroyed in 1953 when its fen habitat was drained (Thorne, 1956). The Jackson Co. discovery confirms the survival of *S. verticillata* in Des Moines River Valley.

The three previously known populations in the Minnesota River Valley were in Scott, Dakota, and Blue Earth Cos. The Scott Co. population was last collected in 1948 and was successfully relocated in 1981. The Dakota Co. population, last collected in 1941, is presumed to have been destroyed in 1978 by road construction. Fortunately, another population was discovered in 1981 about four miles southwest of the destroyed site. The Blue Earth Co. population, last collected in 1883, could not be relocated in 1981. This population was apparently destroyed by industrial development on the outskirts of Mankato.

The nearest known populations to those in Minnesota and Iowa are approximately 200 miles southeast in central Wisconsin (Fig. 1). The apparent

¹Minnesota Natural Heritage Program Contr. 101.

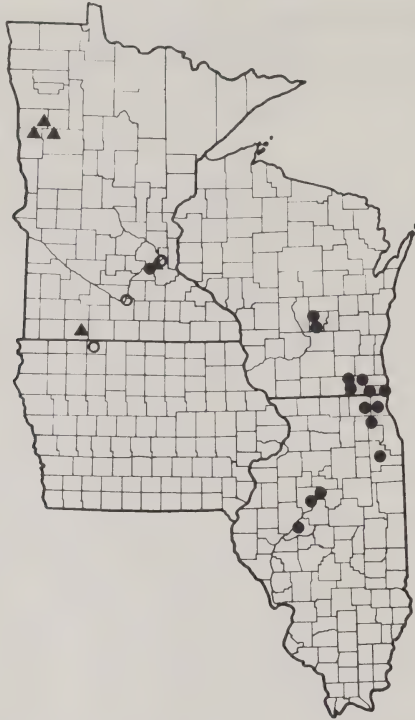


FIG. 1. Distribution of *Scleria verticillata* in the northwestern portion of its range (Minnesota, Wisconsin, Iowa, and Illinois); open circles = vouchered populations presumed to be extinct; solid circles = vouchered populations believed to be extant or where current status is not known to the author; triangles = recently discovered populations reported here. Based on specimens in MIN, ILLS, ILL, WIS, UWM, MOR (only those in MIN examined by the author).

disjunction can be explained by extremely specific ecological requirements. All extant Minnesota populations occur in calcareous fens, as did the extinct Minnesota and Iowa populations. The populations in Wisconsin and Illinois also occur in calcareous fens and infrequently in other habitats where environmental conditions simulate those of fens. Such fen-like habitats include calcareous or alkaline meadows and pannes.² East and south of Illinois, the species becomes less rare, and its habitat requirements less specific.

Available evidence indicates that *S. verticillata* is an obligate fen species in Minnesota. Within fens, it is largely restricted to areas of local disturbance, such as wildlife trails or the margins of pools which often form at the point of groundwater discharge. Under such conditions, it often becomes abundant and occurs with other calcicoles such as *Rhynchospora capillacea*, *Triglochin*

²The term "panne" describes a moist, interdunal depression in calcareous sands on lee sides of dunes on Lake Michigan (Swink & Wilhelm, 1979).



Fig. 2. *Scleria reticulata*.

palustris, *Utricularia minor*, and *Gentiana procera*. It is rarely found in the more stabilized portions of the fen which are frequently dominated by long-lived cespitose species such as *Carex interior*, *C. prairea*, *C. aquatilis* var. *altior*, *C. sterilis*, and *Scirpus cespitosus* var. *callosus*.

Wet prairie and sedge meadow habitats in northwestern Minnesota are floristically and chemically similar to the calcareous fens in that region. All three habitats are sedge- or grass-dominated wetlands with a pH between 7.0 and 8.5, a specific conductivity at 20° C between 732 and 1180, μmho , and a Ca^{2+} concentration between 117 and 218 mg/L. Unlike fens, however, prairies and meadows lack substantial peat accumulation or do not have an internal supply of water (Curtis, 1959). They are, therefore, subject to drying in late summer and autumn. Between 1979 and 1981, more than 50 such prairie and sedge meadow habitats in northwestern Minnesota were searched by the author. *S. verticillata* was found in none of them. It therefore appears that *S. verticillata* requires a season-long supply of cool, calcareous water and a mildly disturbed substrate where competition is minimal. In Minnesota, these conditions appear to exist only in calcareous fens.

The discovery of these populations of *S. verticillata* and the realization of their restrictive habitat requirements help assess the need to protect this species. Biologists have long realized the value of preserving populations of a species occurring at the edge of its range, as well as isolated populations within the main portion of its range. Preserving populations of *S. verticillata* in Minnesota will also protect calcareous fens which are an equally rare plant community characterized by local and discontinuous distribution.

Minnesota specimens examined: Becker Co.: 1 mi. N. of Ogema, NE¼ NE¼ Sec. 13, T142N R42W, *Smith 5790* (MIN). Blue Earth Co.: *Leiberg* (MIN). Clay Co.: 3 mi. E. of Felton, NE¼ NE¼ Sec. 36, T144N R43W, *Smith 5160* (MIN). Dakota Co.: Minnesota Valley, 1 mi. S. of Black Dog Lake in Burnsville, NW¼ NW¼ Sec. 34, T27N R24W, *Smith 4901* (MIN), ½ mi. S. of Nicols, *Moore, Butters & Jenkins 15122* (MIN). Jackson Co.: Des Moines River Valley, NE¼ NE¼ Sec. 7, T103N R35W, *Smith 5314* (MIN). Norman Co.: 2 mi. S. of Faith, SW¼ NW¼ Sec. 25, T144N R43W, *Smith 5160* (MIN). Scott Co.: 1 mi. W. of Savage in the Minnesota Valley, NE¼ SE¼ Sec. 17, T115N R21W, *Smith 5732* (MIN), ¼ mi. S. of Savage, *Rosendahl 7917* (MIN).

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REVIEW

LICHENS OF THE OTTAWA REGION. National Museum of Canada, Syllogeus no. 29, 137 pp. 1981. By Irwin M. Brodo. Free.

Once one knows what species to expect locally, lichens are generally easily recognized at sight, either with a lens or with a naked eye. Relatively few need chemical study, and only the crusts need examination with a microscope. Chemical techniques can be sophisticated in the extreme, but for most of us spot tests with Chlorox or household lye may be sufficient. Keying out unknowns need not be tedious. Mason Hale's *How to Know the Lichens* is remarkably easy to use, and reliable. A more local treatment, such as Brodo's excellent keys to 370 species of the Ottawa region, would help anyone from New England to Minnesota to feel even more comfortable. Dr. Brodo is competent as a lichenologist and skilled at writing. This work, straightforward in presentation, with useful illustrations, as well as an instructive introduction and good glossary, has the distinct advantage of being free on request to the National Museum of Natural History, Ottawa, K1A 0M8. (A French edition is available under the title *Lichens de la région de l'Ottawa*.)

—H. Crum

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On the cover: Leaves from an antheridial
branch of *Sphagnum*, with antheridia;
photo by Jerry Snider

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245 VEGETATION AND FLORISTICS OF WISCONSIN POINT, DOUGLAS COUNTY, WISCONSIN

Rudy G. Koch,¹ Patti Younger,² Leo Bruederle³

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Wisconsin Point, along with Minnesota Point, comprises one of the world's longest fresh water sand bars. Unequally divided by the outlet of the St. Louis River, this sand spit is over 15 km in length. Wisconsin Point, that portion located in Wisconsin, is approximately 5 km long and varies in width from less than 100 m at its base to more than 600 m near the tip (Fig. 1).

Geologically young, the sand spit began to form after the waters of Lake Superior receded to near their present elevation (182 m) 3200 years ago. According to Loy (1963), this spit developed parallel to the storm wave crestline due to the accretion of sands from the south shore (presently accumulating at an estimated 16,820 cubic meters annually) and reached the northern Minnesota shore only a few centuries ago. Analysis of well cores indicates that the sands, gradational with organic-rich sediments from the enclosed bays, vary from 18 to 28 m in depth and overlie a red clay bed (Mengel, 1971).

The climate, greatly modified by the lake, is typical of the western Great Lakes area. The average annual precipitation is 70.9 cm, with 8.9 cm per month from May to August. The growing season is relatively short and average temperatures cool. The wind, predominantly out of the northwest, has been important in the development of the vegetation. For the western Lake Superior region, the typical annual evapotranspiration is less than the expected annual precipitation (Visher, 1966).

Though the diversity of plant species on Wisconsin Point is low, several plant communities, including a mixed pine-birch forest and an extensive beach community, are unique habitats of Wisconsin's Lake Superior shoreline.

In contrast to the typical Wisconsin Lake Superior shore of red clay, the point provides 5 km of sandy shore for recreation. Unfortunately, the sparse beach vegetation is easily disturbed by improper or intensive use. In the interest of a better basis for developing a sound management plan, a study of the vegetation was undertaken. We were interested in compiling a floristic list, quantifying the beach and dune communities most susceptible to disturbance, and delineating and mapping major vegetation types.

In spite of the unique character of Wisconsin and Minnesota Points, little has been published concerning the flora of the sand spit. Land survey records for Douglas County dating from the 1860's include few records from Wisconsin Point, although mention was made of spruce and fir at its base.

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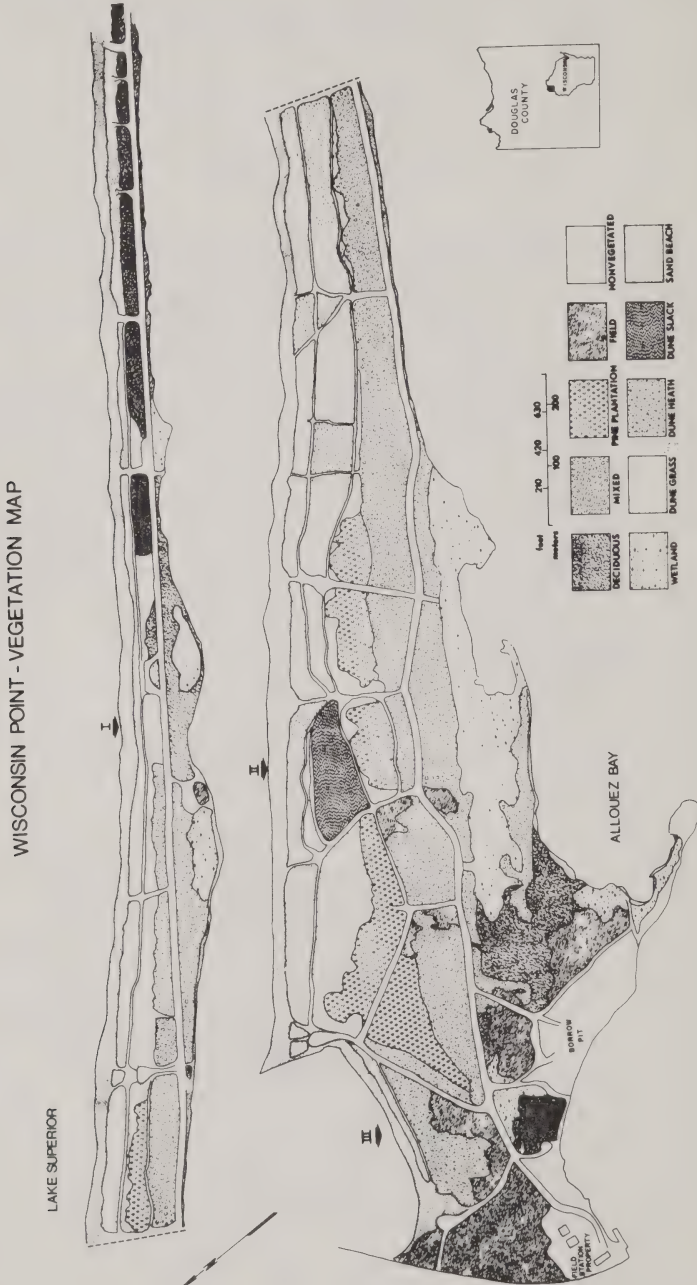


FIG. 1. Location of Wisconsin Point and its major plant communities.

Romans (1966) and Koch (1973) described a portion of the vegetation of Wisconsin Point. Concentrating on the mixed pine stands located on Wisconsin and Minnesota Points, Davidson & Bernard (1969) found that, in spite of a similar appearance, the two stands differ in importance of dominant and sub-dominant tree species. Trees aged from the Wisconsin Point stand ranged up to 140 years old.

Lakela (1939) considered the successional patterns of a sandfill on Minnesota Point. After a four-year period of observation, two wetland communities developed: a willow thicket and a cattail marsh. Davidson & Bernard (1969) reported changes at this site after 30 years. Dabydeen & Koch (1977) studied a nearby sand spoil deposition in Allouez Bay on which were found several plant communities similar to those on Wisconsin Point. Curtis (1959) compared the beach and dune communities of Wisconsin's Lake Superior and Lake Michigan shorelines. He noted the relative scarcity of beach and dune communities on Lake Superior shores when compared to Lake Michigan, as well as differing species composition and decreased diversity.

Intensive sampling was undertaken in order to identify major plant communities, compile a floristic list, and locate rare or endangered species. From early May to late October 1978, the site was visited at two-week intervals. The beach and dune vegetation was sampled in August-September. Quadrats 0.5×2 m were established at 15 m increments beginning at the point of colonization in the lower beach zone. Thirty-five plots were sampled along nine transects. Individuals were tallied by species in order to determine density and frequency values. Dominance was determined on the basis of percent ground cover along the 2-m transect bisecting each quadrat. Importance Percentages (I.P.) were calculated by determining relative dominance, density and frequency (Grieg-Smith, 1964). On the basis of aerial photography provided by the City of Superior and ground survey, the major communities were mapped (Fig. 1).

A total of 267 vascular plant taxa was found. Of 66 families, the Compositae were the largest, with 32 taxa, followed by Gramineae with 25 and Rosaceae with 20 taxa. Eleven taxa in the beach-dune communities had I.P. of 5% or greater (Table 1). Beach grass (*Ammophila breviligulata*) had the highest I.P. values though its importance steadily decreased with distance from the shore. Only dropseed (*Sporobolus cryptandrus*), sedge (*Carex pensylvanica*), and wormwood (*Artemisia campestris*) occurring 75 m inland had higher values.

Eight community types, listed and described below, were mapped (Fig. 1). Non-vegetated areas, such as paths and roads, were also noted as was the sand beach. Schematic cross-sectional views of the point illustrate the diversity of the flora (Fig. 2).

Beach-Dune Grass Community

The beach-dune grass community is a successional community occupying the lower, middle, and upper beach (Cowles, 1899) and dominated by beach grass. This community, as well as the dune communities mentioned later, exhibits an extremely limited distribution along the south shore of Lake Superior with the closest comparable species assemblage found at the mouth of the Flag River at Port Wing, Bayfield Co.

TABLE 1. Importance Percentage of Dune Species ($IP \geq 5\%$)

	Distance from Water (in m)				
	15	30	45	60	75
<i>Ammophila breviligulata</i>	59.5	45.7	39.0	22.1	14.3
<i>Lathyrus maritimus</i>	25.9	12.8	3.1	12.1	1.2
<i>Agropyron repens</i>	8.4	6.2	—	5.9	—
<i>Artemisia campestris</i>		22.0	15.1	20.0	16.2
<i>Salsola kali</i>			9.3	—	—
<i>Sporobolus cryptandrus</i>			6.5	20.1	21.3
<i>Equisetum hyemale</i>			6.8	9.1	—
<i>Polygonella articulata</i>			5.5	4.3	1.8
<i>Carex pensylvanica</i>				5.0	17.9
<i>Poa compressa</i>					9.9
<i>Fragaria virginiana</i>					7.7

The lower beach, though seldom heavily vegetated, is occasionally colonized by beach grass which appears to be encroaching from the middle beach. The latter is delimited on the landward side from the upper beach by a strandline. The strandline is indicated by flotsam at the upper limit of waves during storms. This region is subdominated by beach pea (*Lathyrus maritimus*) and quackgrass (*Agropyron repens*).

With increasing distance from the strandline, beach grass diminishes in importance as sand accretion decreases (Table 1). At the same time there is a

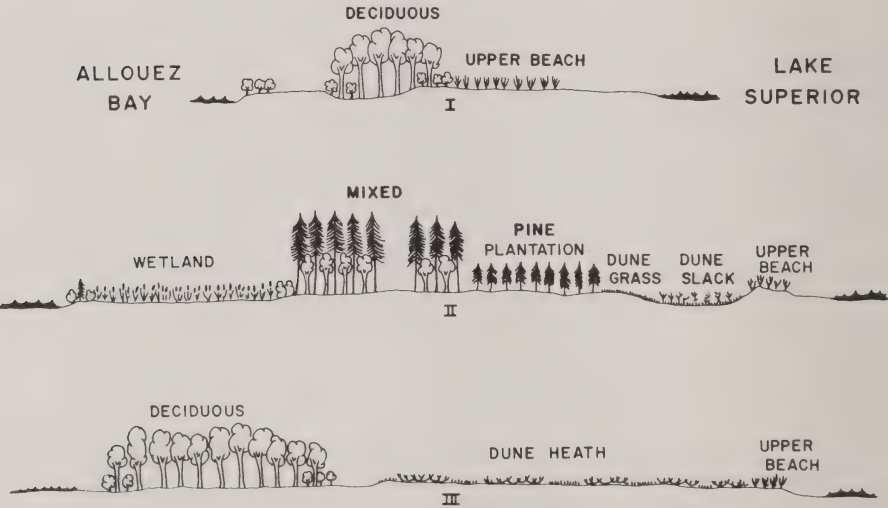


FIG. 2. Cross-sectional portrayal of Wisconsin Point vegetation at the base (I), central portion (II), and near the apex (III).

gradual increase in species diversity due to species characteristic of Lake Michigan's upper beach, such as wormwood, Russian thistle (*Salsola kali*), dropseed, and sedge. Other species of importance are scouring rush (*Equisetum hyemale*), strawberry (*Fragaria virginiana*), jointweed (*Polygonella articulata*), and Canada bluegrass (*Poa compressa*).

This community is extremely sensitive to human use. Once disturbed, this community may never regain its original composition since it developed under conditions which are no longer operating. Foot paths and wheel tracks from off-road vehicles are very slow to heal. Disturbance also results in encroachment of noxious species such as poison ivy (*Rhus radicans*).

Approximately 75 m from the water's edge, near the mixed forest, is an area characterized by a decrease in beach grass and an increase in other graminoids including dropseed, sedge, Canada bluegrass, and sheep fescue (*Festuca ovina* var. *saximontana*). We consider this dune meadow to be part of the beach-dune grass community because of its variable composition, though it could be separately delimited.

Dune Heath

A dune heath, located at the northwestern tip of Wisconsin Point, has developed at the site of deposition for spoils dredged from the harbor. This is the highest of all areas on the point and is extremely susceptible to the desiccating effects of predominantly northwesterly winds. This community is characterized by false heather (*Hudsonia tomentosa* var. *intermedia*) and other mat-forming, prostrate shrubs and woody perennials. Characteristic species are bearberry (*Arctostaphylos uva-ursi*), prostrate juniper (*Juniperus communis* var. *depressa*), and three-toothed cinquefoil (*Potentilla tridentata*). Many herbs dominant in the dune heath (including dropseed, sheep fescue, Canada bluegrass, and sedge) are also common to the dune meadow.

Dune Slack

The dune slack is actually a swale developed in response to disturbance. Approximately 20 years ago this area was an active borrow pit where sand was removed to the level of the water table. This resulted in a secondarily developed wetland dominated by sweet gale (*Myrica gale*) and dwarf birch (*Betula glandulosa* var. *glandulosa*). Several species of willow (*Salix* spp.) and speckled alder (*Alnus rugosa*) are located at the periphery. Herbaceous species are primarily graminoids represented by several species of sedge (*Carex lanuginosa*, *C. aquatilis*, *C. diandra*, and *C. viridula*), rush (*Juncus balticus*), and fowl manna grass (*Glyceria striata*). An endangered species, grass of Parnassus (*Parnassia palustris*), is located here.

Mixed Forest

The mixed forest at the northwest and widest part of Wisconsin Point is believed to be representative of the forest at the time of settlement (Davidson

& Bernard, 1969). This stand is dominated by white pine (*Pinus strobus*), with red pine (*Pinus resinosa*) and paper birch (*Betula papyrifera*) subdominant. The understory is dominated by beaked hazel (*Corylus cornuta*), with other species comprising a shrubby substratum: blueberry (*Vaccinium angustifolium*), velvet-leaf blueberry (*Vaccinium myrtilloides*), red-berried elder (*Sambucus pubens*), bush honeysuckle (*Diervilla lonicera*), and fly honeysuckle (*Lonicera canadensis*).

The herb layer is rather sparse, with several species of importance. Some attractive wildflowers of the boreal forest are found here—bead-lily (*Clintonia borealis*), goldthread (*Coptis trifolia*), wild sarsaparilla (*Aralia nudicaulis*), twin-flower (*Linnaea borealis*), bunchberry (*Cornus canadensis*), shinleaf (*Pyrola* spp.), and starflower (*Trientalis borealis*). Other species of importance are Canada mayflower (*Maianthemum canadense*), northern rice grass (*Oryzopsis asperifolia*), wood anemone (*Anemone quinquefolia*), and fragrant bedstraw (*Galium triflorum*). Although none of these are endangered or threatened, most are highly regarded for aesthetic reasons.

Deciduous Forest

The deciduous forest is the second most common vegetation type. Three subtypes (based on most abundant tree species) are balsam popple (*Populus balsamifera*) at the southeastern end of the point, paper birch occupying the center of the point, and trembling aspen (*Populus tremuloides*) on the bayside of the northwestern end of the sandspit.

The first two stands are dune seres and quite similar in understory composition. Bush honeysuckle, beaked hazel, thimbleberry (*Rubus parviflorus*), red-osier dogwood (*Cornus stolonifera*), chokecherry (*Prunus virginiana*), junberry (*Amelanchier sanguinea*, *A. spicata*) and poison ivy dominate the shrub layer. The herb layer is dominated by meadow rue (*Thalictrum dasycarpum*), nodding Trillium (*Trillium cernuum*), Canada mayflower, false Solomon's seal (*Smilacina stellata*), red baneberry (*Actaea rubra*), fireweed (*Epilobium angustifolium*), wild sarsaparilla, fragrant bedstraw and large-leaved aster (*Aster macrophyllus*).

The trembling aspen stand, on the other hand, occupies the less well-drained site bordering an alder swamp. There is a poorly developed shrub layer with clumps of wild black currant (*Ribes americanum*), red-osier dogwood, red raspberry (*Rubus strigosus*), and red-berried elder. The herb layer also illustrates the poor drainage and is characterized by bluejoint (*Calamagrostis canadensis*), with rock-cress (*Arabis drummondii*), nodding Trillium, touch-me-not (*Impatiens biflora*), and dandelion (*Taraxacum officinalis*) present.

Wetland Communities

Three wetland communities can be identified: alder swamp, emergent aquatic, and shrub carr. Naturally occurring wetlands are restricted to the Allouez Bay side. Due to physical nature and species composition, the communities appear to be in less danger of disturbance than other areas of the point.

Alder swamp, the largest wetland community, is dominated almost exclusively by speckled alder. Subdominant woody species are wild black current, red raspberry and red-berried elder. The herbaceous layer is characterized by nettle (*Urtica dioica*), touch-me-not, bluejoint, common horsetail (*Equisetum arvense*), bitter cress (*Cardamine pensylvanica*), cow parsnip (*Heracleum lanatum*), and bugle weed (*Lycopus americanus*).

The dominant species in the emergent aquatic community are graminoid and primarily sedges (*Carex lacustris*, *C. stricta* and *C. aquatilis*). Other species, though less frequent, are cattail (*Typha latifolia*) and swamp cinquefoil (*Potentilla palustris*). This community is circled by a thicket of speckled alder, red-osier dogwood and willow (*Salix* spp.)

Shrub carr, a community of limited distribution, is dominated by sand bar willow (*Salix interior*) and red raspberry with red-osier dogwood present. There are few herbs.

Pine Plantation

A small area supports a young stand of red pine as a result of planting initiated by a civic organization about 20 years ago. Herbaceous vegetation is reminiscent of the dune meadow aspect of the beach grass community which is adjacent to the plantation and probably characterized the area before planting.

Field

Some areas, chiefly former spoil deposits, have been leveled and seeded. They support a vegetation not unlike the dune heath, though with significantly more weeds.

Non-Vegetated

Roads, paths, a boat launch site, illicit off-road trails, and a recently active borrow pit are essentially devoid of vegetation.

Several endangered species (Read, 1976) are known from Wisconsin Point. Grass of Parnassus (*Parnassia palustris*) is found in fair numbers in the Dune Slack community. Based on observations on Barker's Island, it appears that a soil surface near the water table and restricted competition enable it to thrive. Two other endangered species were collected earlier. Meadow rue (*Thalictrum confine* Fern.) was collected on the point in 1942 by J. W. Thomson, but the current status of the population is unknown. It is possible that this boreal species was adventitive along the shore and did not persist. Likewise, gooseberry (*Ribes oxycanthoides*) was identified from a collection made during the 1930's and has not been collected since.

The extensive use of Wisconsin Point by area residents suggests a need for continued vigilance if the natural communities are to persist. Protection from cutting preserves the mixed forest, though in some areas heavy usage causes disturbance to understory vegetation. Damage to the beach communities from

foot traffic could be lessened with the establishment of board walks. Unfortunately, the relatively remote location from the city of Superior makes protection against vandalism difficult. As a result, structures of this type would tend to be destroyed, and unauthorized off-road activities which cause series damage to the beach communities are difficult to control. Perhaps educational efforts would reduce damage to the habitat.

VASCULAR FLORA OF WISCONSIN POINT

Nomenclature mainly follows Gleason & Cronquist (1963). Families are arranged in the Engler-Prantl sequence, but within families taxa are alphabetical. An asterisk indicates plants not seen. Vouchers are deposited at UW—Superior (SUWS). Habitats are coded BD, beach-dune grass; DH, dune heath; DS, dune slack; MF, mixed forest; DF, deciduous forest; and W, wetland.

Equisetaceae

Equisetum arvense L. W

E. hyemale L. BD

E. sylvaticum L. DF

E. variegatum Schleich. W

Lycopodiaceae

Lycopodium annotinum L. MF

L. clavatum L. MF

L. lucidulum Michx. MF

L. obscurum L. MF

Osmundaceae

Osmunda claytoniana L. DF, W

Polypodiaceae

Dryopteris austriaca v. *spinulosa* (Muell.)

Fiori MF

Pinaceae

Abies balsamea (L.) Mill. MF, DF

Picea glauca (Moench.) Voss. MF

Pinus resinosa Ait. MF, P

P. strobus L. MF

Cupressaceae

Juniperus communis v. *depressa* Pursch. D

Thuja occidentalis L. W

Typhaceae

Typha latifolia L. W

Sparganiaceae

Sparganium eurycarpum Engelm. W, Bay

S. minimum (Hartm.) Fries. W, Bay

Alismataceae

Sagittaria latifolia Willd. W, Bay

Gramineae

Avena fatua L. BD

Agropyron repens (L.) Beauv. BD

A. trachycaulum (Link.) Malte. BD, DH

Agrostis hyemalis v. *tenuis* (Tuckerm.)

G1. BD

Ammophila breviligulata Fern. BD

Bromus ciliatus L. DH, BD, DF

B. inermis Leyss. DF

Calamagrostis canadensis (Michx.) Beauv.

DF, W

Cenchrus longispinus (Hack.) Fern. DH

Elymus canadensis L. BD

E. virginicus L. BD

Digitaria ischaemum (Schreb.) Muhl.

Waste places

Eragrostis pectinacea (Michx.) Nees.

Roads, paths

Festuca ovina v. *saximontana* (Rydb.)

G1. BD

Glyceria striata (Lam.) Hitchc. DS, W

Oryzopsis asperifolia Michx. MF, DF

Panicum lanuginosum L. DH

Phleum pratense L. BD, DH, DF

Poa compressa L. DB, DF, Roads, paths

P. palustris L. W

P. pratensis L. Path and road

Schizachne purpurascens (Torr.) Swall.

BD, DH

Sporobolus cryptandrus (Torr.) Gray BD

Zizania aquatica v. *interior* Fass. W

Cyperaceae

- Carex aquatilis* Wahl. DS, W
C. deweyana Schw. DF
C. diandra Schrank. DS
C. lacustris Willd. W
C. lanuginosa DS
C. lasiocarpa v. *latifolia* (Böck.) Gilly. W
C. pensylvanica BD

Juncaceae

- J. alpinus* Vill. W, DS
J. balticus Willd. DS
J. brevicaudatus (Engelm.) Fern. W

Liliaceae

- Clintonia borealis* (Ait.) Raf. MF, DF
Maianthemum canadense Desf. MF, DF

Iridaceae

- Iris versicolor* L. W

Orchidaceae

- Corallorhiza striata* Lindl. MF
C. trifida Chat. MF, DF

Salicaceae

- Populus tremuloides* DF
P. balsamifera L. DF
Salix bebbiana Sargent. DS, W
S. cordata Muhl. DS

Myricaceae

- Myrica gale* L. DS

Betulaceae

- Alnus rugosa* (Du Roi) Spreng. DS, W
Betula papyrifera Marsh. MF, DF

Urticaceae

- Urtica dioica* v. *procera* (Muhl.) Webb. W

Santalaceae

- Commandra umbellata* (L.) Nutt. DF

Polygonaceae

- Polygonella articulata* (L.) Meissn. BD
Polygonum aviculare L. Paths
P. cilinode Michx. W

Chenopodiaceae

- Chenopodium album* L. Paths
C. glaucum L. Paths
Corispermum hyssopifolium L. BD

Amaranthaceae

- Amaranthus retroflexus* L. Disturbed areas

Caryophyllaceae

- Gypsophila paniculata* L. BD

Nymphaeaceae

- Nuphar variegatum* Engelm. W, Bay

Ranunculaceae

- Anemone canadensis* L. DF, MF
A. quinquefolia L. MF, DF
Actaea rubra (Ait.) Willd. DF
Coptis trifolia (L.) Salisb. MF, DF
Ranunculus acris L. DF, Roadsides

Fumariaceae

- Dicentra cucullaria* (L.) Bernh. MF

- C. projecta* Mackenzie W
C. stricta Lam. W
C. viridula Michx. DS
C. umbellata Schk. DS, BD
Cyperus schweinitzii Torr. BD, DH
Eleocharis acicularis (L.) R. & S. W

- J. dudleyi* Wieg. Roadside
J. nodosus L. W
J. tenuis Willd. Paths

- Smilacina stellata* (L.) Desf. DF, MF
Trillium cernuum L. DF

- Habenaria hyperborea* (L.) R. Br. W

- S. interior* Rowl. BD, W
S. petiolaris Sm. W, DF
S. rigida Muhl. W

- B. pumila* v. *glandulifera* Regel. DS
Corylus cornuta Marsh. MF, DF

- P. punctatum* Ell. W
Rumex acetosella L. DH, DF
R. orbiculatus Gray. W

- Cycloloma atriplicifolium* (Spreng.) Coult. BD
Salsola kali v. *tenuifolia* G.F.W. Meyer BD

- Silene cserei* Baumg. Roads and paths

- N. microphyllum* (Pers.) Fern. W, Bay

- R. septentrionalis* Poir. W
 **Thalictrum confine* Fern.
T. dasycarpum Fisch. & Ave.-Lall. DF
T. dioicum L. DF
T. polygamum Muhl. DF

Cruciferae

- Arabis divaricarpa* A. Nels. BD
A. drummondii Gray BD
A. hirsuta (L.) Scop. DF
A. laevigata (Muhl.) Roir. BD
Berteroa incana (L.) DC. BD, Roadsides

Saxifragaceae

- Parnassia palustris* L. DS
Ribes americanum Mill. DF, W
R. glandulosum Grauer DF

Rosaceae

- Agrimonia pubescens* Wallr. BD
Amelanchier sanguinea (Pursh.) DC. DF
A. spicata (Lam.) K. Koch DF
Fragaria vesca L. BD, DH, Roadsides
F. virginiana Duchesne BD
Geum aleppicum v. *strictum* (Ait.) Fern.
 BD, DH
Physocarpus opulifolius (L.) Maxim. DF,
 Bayshore
Potentilla norvegica L. Roadsides
P. palustris (L.) Scop. W

Leguminosae

- Lathyrus maritimus* (L.) Bigel. BD
L. ochroleucus Hook. DF
Melilotus alba Desr. BD, Roadside
M. officinalis (L.) Desr. Roadside

Oxalidaceae

- Oxalis stricta* L. DF

Callitrichaceae

- Callitriche palustris* L. Bay

Anacardiaceae

- Rhus radicans* L. BD, DF

Aceraceae

- Acer negundo* L. DF
A. rubrum L. DF

Balsaminaceae

- Impatiens biflora* Walt. DF, W

Vitaceae

- Parthenocissus* sp. DF

Hypericaceae

- Hypericum majus* (Gray) Britt. W, DS

Elatinaceae

- Elatine triandra* Schk. W

Cistaceae

- Hudsonia tomentosa* v. *intermedia* Peck.
 DH

Violaceae

- Viola adunca* Sm. MF
V. conspersa Reichenb. MF

Lythraceae

- Lythrum salicaria* L. W

Onagraceae

- Epilobium angustifolium* L. DF
Oenothera biennis L. BD

Araliaceae

- Aralia nudicaulis* L. MF, DF

- Brassica kaber* (DC.) L. Wheeler Roadsides

- Cardamine pensylvanica* Muhl. W

- Lepidium densiflorum* Schrad. Roadsides

- Sysimbrium altissimum* L. W

- Thlaspi arvense* L. Roadsides

- R. hirtellum* Michx. DF

- **R. oxyacanthoides* L.

- R. triste* Pall. W

- P. tridentata* Ait. D

- Prunus pensylvanica* L. DF

- P. pumila* L. BD

- P. virginiana* L. DF

- Rosa acicularis* Lindl. DF

- R. blanda* Ait. DF

- R. rugosa* Thunb. Roadside

- Rubus parviflorus* Nutt. DF

- R. strigosus* Michx. DF, W

- Sorbus americana* Marsh. DF

- S. decora* (Sarg.) C. K. Schneid. DF

- Trifolium hybridum* L. BD, Roadside

- T. repens* L. BD, DH, Roadside

- Vicia americana* Muhl. DF

- R. typhina* L. DF

- A. spicatum* Lam. DF, MF

- H. ellipticum* Hook. W

- V. pubescens* Ait. DF

- V. renifolia* Gray. MF

- O. parviflora* L. BD

Umbelliferae

- Carum carvi* L. BD, DH, Roadside
Cicuta bulbifera L. W
C. maculata L. W
Daucus carota L. BD
Heracleum lanatum Michx. W

Cornaceae

- Cornus canadensis* L. MF

Pyrolaceae

- Pyrola elliptica* Nutt. DF, MF

Ericaceae

- Arctostaphylos uva-ursi* (L.) Spreng. D
Vaccinium angustifolium Ait. DF, MF

Primulaceae

- Lysimachia ciliata* L. W

Oleaceae

- Fraxinus pennsylvanica* Marsh. DF, Roadside

Gentianaceae

- Gentiana andrewsii* f. *albiflora* Britt. W, DS

Apocynaceae

- Apocynum sibiricum* Jacq. Roadside

Asclepiadaceae

- Asclepias syriaca* L. Roadside

Polemoniaceae

- Collomia linearis* Nutt. DH

Boraginaceae

- Mertensia paniculata* (Ait.) G. Don. DF

Labiateae

- Agastache foeniculum* (Pursh.) Ktze. BD
Galeopsis tetrahit L. Waste places
Lycopus americanus Muh. W
Physostegia parviflora Nutt. W

Solanaceae

- Solanum dulcamara* L. Waste places

Scrophulariaceae

- Gerardia tenuifolia* v. *parviflora* Nutt. DS
Linaria vulgaris Hill. Roadsides, BD
Melampyrum lineare v. *americanum* (Michx.) Beauv. DF, MF

Lentibulariaceae

- Utricularia vulgaris* v. *americana* Gray W

Plantagenaceae

- Plantago major* L. Roadside, paths

Rubiaceae

- Galium triflorum* Michx. MF

Caprifoliaceae

- Diervilla lonicera* Mill. MF, DF
Linnaea borealis L. MF
Lonicera canadensis Marsh. MF
L. dioica L. DF

Valerianaceae

- Valeriana officinalis* L. DF

Campanulaceae

- Campanula aparinoides* Pursh. W

- Osmorhiza claytonii* (Michx.) Clarke. DF
O. longistylis (Torr.) DC. DF, MF
Sanicula marilandica L. MF
Sium suave Walt. W
Zizia aurea (L.) Koch DH

- C. stolonifera* Michx. DF, W

- P. asarifolia* Michx. MF

- V. myrtilloides* Mich. DF, MF

- Trientalis borealis* Raf. MF

- F. nigra* Marsh. DF

- G. andrewsii* Griseb.

- Halenia deflexa* (Sm.) Griseb. DF

- Lycopus uniflorus* Michx. W

- Mentha arvensis* L. W

- Scutellaria galericulata* L. W

- Stachys hispida* Pursh. Roadside

- Mimulus ringens* L. W

- Scrophularia lanceolata* Pursh. DF

- Verbascum thapsus* L. Waste places

- L. hirsuta* Eat. DF

- Sambucus pubens* Michx. MF, DF, W

- Viburnum opulus* L. MF

- C. rotundifolia* L. DF

Compositae

- Achillea millefolium* L. BD, DH
Ambrosia artemisifolia L. Waste places, DH
Anaphalis margaritacea (L.) C. B. Clarke DH
Arctium minus Schk. BD
Artemisia campestris L, BD
Aster ciliolatus Lindl. DF
A. lateriflorus (L.) DF
A. macrophyllus L. DF, MF
A. puniceus L. DF
A. simplex Willd. DF
Chrysanthemum leucanthemum L. DH, Roadsides
Cirsium arvense (L.) Scop. DH
Erigeron philadelphicus L. DF
Eupatorium maculatum L. W
Euthamia graminifolia (L.) Nutt. DH, BD
Grindelia squarrosa (Pursh.) Dunal. DH
Helianthus annuus L. DH, Roadside
H. maximiliani Schrader. Roadside
Hieracium aurantiacum L. DH, DF
Lactuca canadensis L. DF
Matricaria maritima L. Roadside, waste places
M. matricarioides (Less.) Porter Waste places
Prenanthes alba L. DF
Rudbeckia hirta L. BD, DH
Senecio plattensis Nutt. DS
Solidago canadensis L. BD
S. gigantea v. *serotina* (Kuntze) Cronq. BD, DH
S. hispida Muhl. BD, DH
S. nemoralis Ait. BD, DH
Sonchus oleraceus L. Waste places
S. uliginosus Bieb. Waste places
Taraxacum officinale Web. DF, Road-sides

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245 LICHEN SURVIVAL IN A BURNED OAK SAVANNA 576

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There have been numerous studies on the effects of fires on lichens in the boreal coniferous forests (Ahti, 1977 and references there), but little has been done in other vegetational types. Rossman (1977) mentioned the effects of fires on *Peltigera rufescens* in a "biscuit scabland prairie" in Oregon, and Wetmore (1965) studied succession after fires in dry ponderosa pine forests in the Black Hills, but neither of these studies considered lichens on trees. Brodo (1968) discussed the effects of fire on corticolous lichens in pine forests. The present study of the effects of ground surface fires on lichens in an oak savanna in east-central Minnesota was done in the Helen Allison Savanna Natural Area, owned by The Nature Conservancy and located in Anoka County just south of the Cedar Creek Natural History Area, about 35 miles north of Minneapolis.

The terrain is gently rolling with some low wet areas and some dry knolls with sand blowouts. Part of the western end is an abandoned field with only a few scattered trees and was not included in this study. The forested oak savanna is 550 m in the east-west direction and 410 m in the north-south direction with bur oak (*Quercus macrocarpa*), northern pin oak (*Quercus ellipsoidalis*), and some scattered green ash (*Fraxinus pennsylvanica*) and other trees.

This scantily wooded area was divided into five north-south strips from the eastern edge for experimental burning; these strips are called burn units in this report. The northern halves of the burn units were burned according to the following schedule every year since 1962, but the southern halves were intermittently burned between 1962 and 1978. Since 1978 the complete strips have been burned every year. The eastern burn unit (burn unit 1) has been burned almost every year since 1962 and extends from the east fence to about 95 m. The second burn unit, from 95 m to 126 m, has been burned three out of four years. Burn unit three extends from 126 m to 160 m; it has been burned two out of four years. Burn unit four extends from 160 m to 180 m and has been burned one out of every four years. Burn unit five includes all of the wooded area west of 180 m and has not been burned for at least 50 years.

During the first year of this project (1980) a general lichen flora was prepared, terricolous lichens were sampled, and 88 trees were randomly selected for study of the corticolous lichens. All trees were selected without regard to species, shading, or slope of the ground, and circular line transects were laid out along the girths at the base, at 0.75 m and at 1.5 m above the soil surface on the trunks. There were 52 species of lichens on the trees and 13 on the ground (Wetmore, 1981). There was a general trend of reduction in lichens on the lower parts of the trees with an increase in fire frequency, but due to inadequate sampling of trees in some of the burn units and other uncontrolled variables, it was determined that a resurvey should be done in 1981 in which only one species of tree would be studied and the trees should be matched for shading and ground slope.

Bur oak is the most common tree, and all sampling was restricted to 20 mature trees of this species over 100 cm circumference at breast height, with the exception of one tree which was only 88 cm. Trees selected in each burn unit had similar shading from nearby trees and were on similar ground slopes. This resulted in one tree in each burn unit with southwest shading, one with northwest shading, one with southeast shading and one with no



FIG. 1. The most frequently burned portion of Allison Savanna (burn unit 1), showing the wide spacing of oaks.

surrounding shade. The 20 trees were marked with a numbered aluminum tag for future reference. Three bands around each tree were established for plots. The band at the base was 5 cm above the highest point of soil, the mid-band was 0.75 m above the base band, and the top band was 1.5 m above the base band. Four 20 cm \times 10 cm permanent plots were located in each band (N,E,S,W), and the upper right and lower left corners of each plot were marked with 5 cm nails 2.5 mm diameter and 5 cm long made from stainless steel welding rod. A transparent plastic overlay sheet was used to establish plot boundaries. In each plot the number of thalli and percent cover were recorded for each lichen species, and the presence of fire scars and other abnormal features were noted.

Summaries of lichen occurrence as measured by numbers of species and percent cover with regard to degree of shading showed no consistent correlations. Summaries of numbers of species and percent cover with regard to compass direction on the trunks showed only a slight reduction in both parameters on the south side of the tree in some burn units, but in burn unit two the maxima also occurred on the south side of the trees.

Table 1 lists the average cover by species for trees in each burn unit. Table 2A lists the average numbers of species per band (base, mid, top) by burn unit, and table 2B shows the average percent cover by burn unit. These both show lower values in the mid- and the base bands compared with the top band as fire frequency increases, with the base band showing the lowest values.

Comparing the percent cover and numbers of thalli of individual lichen species in the different burn units shows similar trends. Tables 3, 4, 5 and 6 show comparisons for four typical species. All these species show lower values in the base band with any fire frequency. *Xanthora fallax* also shows much lower values

TABLE 1. Average cover (%) by burn unit and tree band. + = < 1%. BU1 = burn unit; B = base band; M = mid band; T = top band.

	BU1			BU2			BU3			BU4			BU5		
	B	M	T	B	M	T	B	M	T	B	M	T	B	M	T
<i>Arthonia caesia</i>			+			+									
<i>Bacidia chlorococca</i>	4	3													
<i>Caloplaca chrysophthalma</i>	+		+			+							+	+	+
<i>C. flavorubescens</i>								1		+	+		5	5	5
<i>C. microphyllina</i>							1	9		+			+	1	+
<i>C. ulmorum</i>	+		+												
<i>Candelaria concolor</i>	1	11	16	+	2	5	+	3	10	+	2	2	+	1	5
<i>Candelariella xanthostigma</i>		+	2		+	+	+	2	5	+	2	9	1	13	8
<i>Hyperphyscia adglutinata</i>	3	5	10	+	1	13		1	+		9	3	8	19	8
<i>H. syncolla</i>													1		
<i>Lecanora impudens</i>													+	1	1
<i>L. symmictera</i>											+				
<i>Parmelia bolliana</i>			+			1		2		1	3	6	4	6	10
<i>P. caperata</i>						+		1		1			13		1
<i>P. flaventior</i>		+	+	+	+	+	4	15		3	12	30	1	23	8
<i>P. rudecta</i>					+	+	1	10		+	1	9	+	7	10
<i>P. soredica</i>											8	27			
<i>P. sulcata</i>															1
<i>Phaeophyscia cernohorskyi</i>	+	+	6				+	2					1	3	5
<i>P. chloantha</i>	1	5	3	1		+	+	+			+			2	2
<i>P. orbicularis</i>	1		+				1	1		+	1			1	8
<i>P. rubropulchra</i>										7			8		
<i>Physcia aipolia</i>			1										1	1	1
<i>P. americana</i>		+	1				1	3		+			21	9	6
<i>P. millegrana</i>	1	26	24	1	31	23	+	19	19	18	80	54	36	28	20
<i>P. stellaris</i>															+
<i>Physconia detera</i>			2				+	5			+		6	1	2
<i>Rinodina papillata</i>	+	7	2	1	20	33	+	10	16	15	33	33	15	21	16
<i>Xanthoria fallax</i>	+	1	1		+	+	+	1	5	+	+	1	8	9	12
<i>X. polycarpa</i>		+													

TABLE 2. Occurrence of lichens in base (B), mid- (M) and top (T) bands.

A. Average number of species				B. Average cover (%)			
	B	M	T		B	M	T
BU1	1.55	4.65	4.87	BU1	2.36	14.67	16.72
BU2	1.55	3.05	4.22	BU2	0.90	13.40	18.55
BU3	1.05	3.82	5.31	BU3	0.35	10.67	25.80
BU4	3.00	4.67	5.27	BU4	13.05	36.80	44.22
BU5	5.60	7.02	7.57	BU5	35.85	36.65	31.35

TABLE 3. Average cover (%) and average number of thalli per plot in base (B), mid- (M) and top (T) band for *Physcia millegrana*. + = < 1%.

A. Average percent cover				B. Average number of thalli			
	B	M	T		B	M	T
BU1	1	26	24	BU1	7	62	52
BU2	1	31	23	BU2	16	83	75
BU3	+	19	19	BU3	4	39	49
BU4	18	80	54	BU4	60	144	120
BU5	36	28	20	BU5	44	42	45

TABLE 4. Average cover (%) and average number of thalli per plot in base (B), mid- (M) and top (T) band for *Xanthoria fallax*. + = < 1%.

A. Average percent cover				B. Average number of thalli			
	B	M	T		B	M	T
BU1	+	1	1	BU1	1	11	12
BU2	0	+	+	BU2	0	1	4
BU3	+	1	5	BU3	1	15	50
BU4	+	+	1	BU4	0	1	10
BU5	8	9	12	BU5	39	62	79

TABLE 5. Average cover (%) and average number of thalli per plot in base (B), mid- (M) and top (T) band for *Rinodina papillata*. + = < 1%.

A. Average percent cover				B. Average number of thalli			
	B	M	T		B	M	T
BU1	+	7	2	BU1	0	7	6
BU2	1	20	33	BU2	1	13	16
BU3	+	10	16	BU3	1	11	13
BU4	15	33	33	BU4	7	20	22
BU5	15	21	16	BU5	6	20	12

TABLE 6. Average cover (%) and average number of thalli per plot in base (B), mid- (M) and top (T) band for *Candelariella xanthostigma*. + = < 1%.

A. Average percent cover				B. Average number of thalli			
	B	M	T		B	M	T
BU1	0	+	2	BU1	0	3	7
BU2	0	+	+	BU2	0	0	4
BU3	+	2	5	BU3	0	5	17
BU4	+	2	9	BU4	0	11	25
BU5	1	13	8	BU5	3	14	14

in the mid-band with any fire, but *Physcia millegrana* and *Rinodina papillata* show much less reduction in values in the mid-band. *Candelariella xanthostigma* shows lower values in both the mid- and top bands, especially at higher burn frequencies. Most other species show similar trends, but were much less abundant in all burn units.

A few species have higher values in the burned than in the unburned areas at most burning frequencies and levels. *Phaeophyscia chloantha* and *Candelaria concolor* are most notable; table 7 shows the values for the latter. This effect may be due to increased sunlight on the trunks, but there is also more wind and consequently probably lower humidity. In burn unit 5, which has not been burned for more than 50 years, branches occur to very near the bases of trees, while in the burned areas low branches are usually not present. Some species

TABLE 7. Average cover (%) and average number of thalli per plot in base (B), mid- (M) and top (T) band for *Candelaria concolor*. + = < 1%.

A. Average percent cover				B. Average number of thalli			
	B	M	T		B	M	T
BU1	1	11	16	BU1	15	74	100
BU2	+	2	5	BU2	5	31	63
BU3	+	3	10	BU3	12	27	66
BU4	+	2	2	BU4	6	34	37
BU5	+	1	5	BU5	8	17	28

that persist in the burned areas, such as *Physcia millegrana* and *Candelaria concolor*, grow in cracks of bark and might escape some heat of the fire. This persistence in the burned areas may be due to a lack of competition from more fire-sensitive species or to the protected microhabitat where the species typically grow. Some lichens that appear to survive at tree bases in burn units three and four may have escaped burning because of the direction of the fire and may survive several fires until a fire comes from another direction (Brodo, 1968). Also, burning has been much less intense and complete some years than others. These data, therefore, cannot be used with confidence to estimate the rate of lichen colonization of the tree trunks.

A few species might be eliminated by repeated fires. *Caloplaca flavorubescens* is moderately abundant in the unburned unit, but almost absent in burned areas. *Phaeophyscia rubropulchra* occurs mainly at the base of trees in the unburned unit and is absent in all burned units except unit 4. *Lecanora impudens* is the only species that seems to be completely absent from all the burned units, but this may not be significant since it is rare even in unburned unit 5.

An important factor in the occurrence of lichens in this study is the presence of the basidiomycete *Aleurodiscus* which grows on the bark and digests the surface. This fungus infects *Quercus*, and in the Allison Savanna *Q. macrocarpa* is much more heavily damaged by it than the other oaks. On trees heavily infected with *Aleurodiscus* there are few lichens, even in unburned areas. Some

irregularity of the data in the tables is due to this factor. A different tree species, less damaged by *Aleurodiscus*, might have provided less conclusive results because different trees do not have the same lichens. In this study area more species occur on the bur oak than on the northern pin oak, and this can be related to bark texture, pH, and moisture holding capacity (Hale, 1955; Brodo, 1968; Barkman, 1958). The ash trees on the tract have bark texture similar to that of bur oak and also have many lichens and are not infected by *Aleurodiscus*, but they are not abundant or evenly distributed enough to be able to match trees in all burn units. Northern pin oak was also not chosen for this survey because it is much less abundant and has fewer lichens.

The tables showing numbers of thalli and those showing percent cover do not agree in all cases. The number of thalli in several species which produce separate lobes or squamules (such as *Physcia* and *Candelaria*) or grow as discontinuous thalli (*Rinodina papillata* which grows mainly in bark cracks) is not as reliable as percent cover of such species. The absolute numbers of thalli cannot be reliably determined in many cases, even if all the counting is done by one person (as in this study).

The results of the second study generally agree with those from the 1980 study, but the advantage is that several of the variables have been eliminated; the disadvantages are that more time consuming sampling techniques necessitated sampling fewer trees so that the effects of a single tree with heavy disturbance or abnormal growth or with bark heavily infected with *Aleurodiscus* introduce significant variation in the results.

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CAREX OF NORTHEASTERN MINNESOTA: COOK,
LAKE, ST. LOUIS, AND ITASCA COUNTIES

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In northern Minnesota, deciduous, pine, and boreal forest elements create a mosaic of forest types. Because the vegetation cannot be characterized by a single species or group of only coniferous or deciduous species, much of it has been mapped (Küchler, 1964, Cushing, 1965) as mixed conifer-hardwood forest. Owing to the mingling forest elements, many northern *Carex* species have distributions in the state that are relatively similar, even though particular sets of species grow in clearly dissimilar habitats. This paper focuses on the carices of northeastern Minnesota, in Cook, Lake, St. Louis, and Itasca counties (Fig. 1); all specimens cited are deposited at the University of Minnesota Herbarium (MIN). Lakela (1965) reported 87 species from St. Louis and Lake Cos. Re-examination of her material reveals that four must be excluded, and seven others added. Quite recently three additional species have been found in one or both of the counties. Butters & Abbe (1953) reported 55 species from Cook Co.; since then five additional carices have been discovered. Wheeler (1977) reported 68 species from Itasca Co., and recently two species have been added.

Although few aspects regarding *Carex* in northeastern Minnesota can be covered in this paper, it seems relevant to discuss the disparity in the number of species occurring in the western and eastern portions of the study area and the carices that have special geographic interest.

At present 98 species are known from the four-county area (Table 1). Many of them are common throughout the study area, whereas others, such as *C. exilis*, *C. livida*, and *C. vaginata*, are only occasional. Yet other species, including *C. garberi*, *C. katahdinensis*, *C. michauxiana*, *C. pallescens*, *C. supina*, and *C. xerantica*, are known from only one or two stations in northeastern Minnesota and occur nowhere else in the state.

Fewer species of *Carex* are known from Cook and Lake Cos. than from St. Louis and Itasca Cos. This is not unexpected, because the areas of the counties are clearly different, and the habitat diversity is greater in the latter two counties.

Several species flourish in alluvial woodlands along the St. Louis River (St. Louis Co.) and Mississippi River (Itasca Co.). Such habitats are poorly represented in the extreme northeast (Lake and Cook Co.) where the rivers flow swiftly down a steep slope to Lake Superior. However, even in Itasca and St. Louis Cos. floodplain forests occur only where well-developed meanders of large, slow-flowing rivers are subject to flooding. Some species in these floodplains, namely *C. alopecoidea*, *C. assiniboinensis*, *C. cristatella*, *C. emoryi*, *C. lupulina*, and *C. rosea*, are unknown from Lake and Cook Cos. Although few stations are known

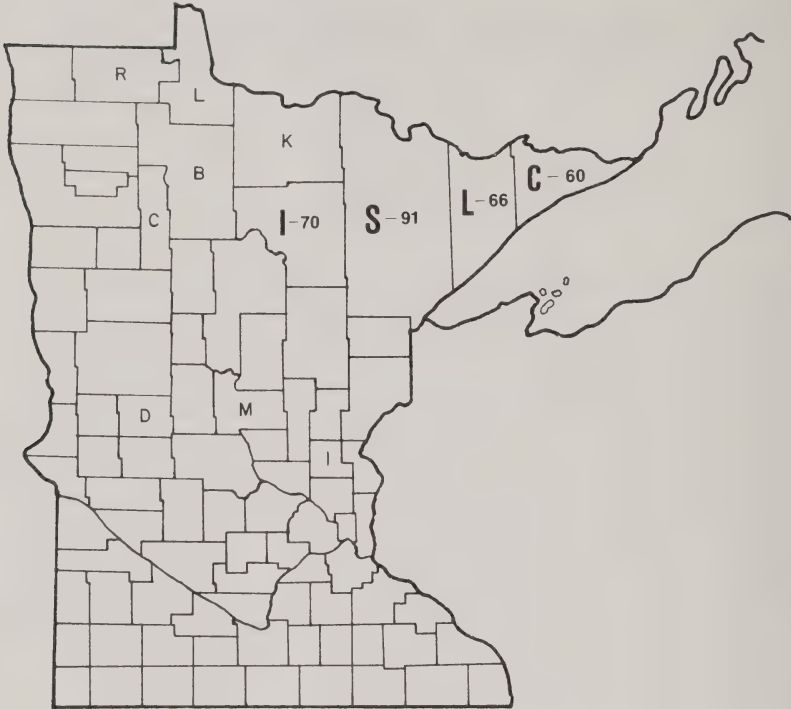


FIG. 1. Major counties investigated and number of *Carex* species known in each (C = Cook; L = Lake; S = St. Louis; I = Itasca). Other counties mentioned (K = Koochiching; B = Beltrami; L = Lake of the Woods; R = Roseau; C = Clearwater; D = Douglas; M = Morrison; I = Isanti).

for the above-mentioned carices, *C. assiniboinensis* is abundant at some localities. This species often bears long-arching sterile culms that upon reaching the ground form new plants at the tips. These vegetative structures can, in some floodplain forests, form the dominant ground cover. Vegetative reproduction in *C. assiniboinensis* has been discussed by other workers (Tolstead, 1946; Stevens, 1950; Bernard, 1959; Hudson, 1977).

Sugar maple-basswood-dominated forests, frequent in southern Itasca Co. (less so in St. Louis Co.), are of only local occurrence in Lake and Cook Cos. No less than 13 species of *Carex* grow in these forests; three of them, *C. pensylvanica*, *C. rosea*, and *C. sprengelii*, are unknown from Lake and Cook Cos. Interestingly, most carices in these forests appear to have a random distribution, but that of *C. pedunculata*, a known myrmecochore (Handel, 1976, 1978), is often clearly non-random, the majority of colonies occurring on rotting logs (often to the exclusion of other vascular plants) and near bases of trees. Most *Carex* species that grow in these forests also grow in other habitats, some of which (e.g. aspen woodlands) occur throughout the four-county area.

TABLE 1. *Carex* of Cook, Lake, St. Louis, and Itasca Counties

	Itasca	St. Louis	Lake	Cook
<i>C. abdita</i> Bickn. ^{1,2}	—	+	+	+
<i>C. adusta</i> Boott ^{1,2,3}	+	+	+	+
<i>C. aenea</i> Fern. ^{1,2,3}	+	+	+	+
<i>C. alopecoidea</i> Tuckerm. ³	+	—	—	—
<i>C. angustior</i> Mack. ^{1,2,3}	+	+	+	+
<i>C. aquatilis</i> Wahlenb. ^{1,2,3}	+	+	+	+
<i>C. arcta</i> Boott ^{1,3}	+	+	+	+
<i>C. arctata</i> Boott ^{1,2,3}	+	+	+	+
<i>C. assiniboinensis</i> W. Boott ^{1,3}	+	+	—	—
<i>C. atherodes</i> Spreng. ^{1,3}	+	+	—	—
<i>C. aurea</i> Nutt. ^{1,2,3}	+	+	+	+
<i>C. backii</i> Boott ^{1,2}	—	+	+	+
<i>C. bebbii</i> (Bailey) Fern. ^{1,3}	+	+	+	+
<i>C. bicknellii</i> Britt.	—	+	—	—
<i>C. brevior</i> (Dew.) Mack. ^{1,3}	+	+	—	—
<i>C. brunnescens</i> (Pers.) Poir. ^{1,2,3}	+	+	+	+
<i>C. buxbaumii</i> Wahlenb. ^{1,2}	—	+	+	+
<i>C. canescens</i> L. ^{1,2,3}	+	+	+	+
<i>C. castanea</i> Wahlenb. ^{1,2,3}	+	+	+	+
<i>C. cephalantha</i> (Bailey) Bickn. ^{2,3}	+	+	+	+
<i>C. chordorrhiza</i> L. f. ^{1,3}	+	+	+	+
<i>C. communis</i> Bailey ^{1,2}	—	+	+	+
<i>C. comosa</i> Boott ^{1,3}	+	+	+	—
<i>C. conoidea</i> Willd. ¹	—	+	—	—
<i>C. crawei</i> Dew. ¹	—	+	—	—
<i>C. crawfordii</i> Fern. ^{1,2,3}	+	+	+	+
<i>C. crinita</i> Lam. ^{1,2,3}	+	+	+	+
<i>C. cristatella</i> Britt. ^{1,3}	+	+	—	—
<i>C. cryptolepis</i> Mack. ^{1,2}	—	+	+	+
<i>C. debilis</i> Michx.	+	—	—	—
<i>C. deflexa</i> Hornem. ^{1,2}	—	+	+	+
<i>C. deweyana</i> Schwein. ^{1,2,3}	+	+	+	+
<i>C. diandra</i> Schrank. ^{1,3}	+	+	+	—
<i>C. disperma</i> Dew. ^{1,2,3}	+	+	+	+
<i>C. emoryi</i> Dew. ³	+	+	—	—
<i>C. exilis</i> Dew.	—	+	+	—
<i>C. flava</i> L. ¹	—	+	+	+
<i>C. foenea</i> Willd. ^{1,3}	+	+	—	—
<i>C. garberi</i> Fern.	—	+	—	—
<i>C. gracillima</i> Schwein. ^{1,2,3}	+	+	+	+
<i>C. granularis</i> Willd. ¹	—	+	—	—
<i>C. gynandra</i> Schwein.	—	+	+	—
<i>C. gynocrates</i> Drej. ^{1,3}	+	+	—	—
<i>C. haydenii</i> Dew. ¹	—	+	—	—
<i>C. houghtoniana</i> Dew. ^{1,2,3}	+	+	+	+
<i>C. hystericina</i> Willd. ^{1,2,3}	+	+	+	+
<i>C. interior</i> Bailey ^{1,3}	+	+	+	—
<i>C. intumescens</i> Rudge ^{1,2,3}	+	+	+	+
<i>C. katahdinensis</i> Fern. ¹	—	+	—	—
<i>C. lacustris</i> Willd. ^{1,3}	+	+	+	—
<i>C. lanuginosa</i> Michx. ^{1,3}	+	+	+	—
<i>C. lasiocarpa</i> Ehrh. ^{1,2,3}	+	+	+	+
<i>C. lenticularis</i> Michx. ^{1,2}	—	+	+	+

TABLE 1. Continued

	Itasca	St. Louis	Lake	Cook
<i>C. leptalea</i> Wahlenb. ^{1,2,3}	+	+	+	+
<i>C. leptonervia</i> Fern. ^{1,2,3}	+	+	+	+
<i>C. limosa</i> L. ^{1,2,3}	+	+	+	+
<i>C. livida</i> (Wahlenb.) Willd. ²	—	+	+	+
<i>C. lupulina</i> Willd. ^{1,3}	+	+	—	—
<i>C. media</i> R. Br. ^{1,2}	—	—	+	+
<i>C. merritt-fernaldii</i> Mack. ^{1,2,3}	+	+	+	+
<i>C. michauxiana</i> Boeckl. ²	—	—	—	+
<i>C. oligosperma</i> Michx. ^{1,3}	+	+	+	—
<i>C. ormostachya</i> Wieg. ^{1,2,3}	+	+	—	+
<i>C. pallescens</i> L. ¹	—	+	—	—
<i>C. pauciflora</i> Lightf. ^{1,2,3}	+	+	+	+
<i>C. paupercula</i> Michx. ^{1,2,3}	+	+	+	+
<i>C. peckii</i> Howe ^{1,2,3}	+	+	+	+
<i>C. pedunculata</i> Willd. ^{1,2,3}	+	+	+	+
<i>C. pennsylvanica</i> Lam. ^{1,3}	+	+	—	—
<i>C. praegracilis</i> W. Boott	—	+	+	—
<i>C. prairea</i> Dew. ^{1,3}	+	+	—	—
<i>C. praticola</i> Rydb. ²	—	—	+	+
<i>C. projecta</i> Mack. ^{1,2,3}	+	+	+	+
<i>C. pseudo-cyperus</i> L. ^{1,3}	+	+	+	—
<i>C. retrorsa</i> Schwein. ^{1,2,3}	+	+	+	+
<i>C. richardsonii</i> R. Br. ^{1,3}	+	+	—	—
<i>C. rosea</i> Willd. ^{1,3}	+	+	—	—
<i>C. rostrata</i> Stokes ^{1,2,3}	+	+	+	+
<i>C. scoparia</i> Willd. ^{1,2,3}	+	+	+	+
<i>C. sprengelii</i> Spreng. ^{1,3}	+	+	—	—
<i>C. stipata</i> Willd. ^{1,2,3}	+	+	+	+
<i>C. stricta</i> Lam. ^{1,2,3}	+	+	+	+
<i>C. supina</i> Willd. ²	—	—	—	+
<i>C. synchocephala</i> Carey ^{1,3}	+	+	+	—
<i>C. tenera</i> Dew. ^{1,3}	+	+	+	—
<i>C. tenuiflora</i> Wahlenb. ^{1,2,3}	+	+	+	+
<i>C. tetanica</i> Schkuhr	—	+	—	—
<i>C. tonsa</i> (Fern.) Bickn. ^{1,2}	—	+	+	+
<i>C. torreyi</i> Tuckerm. ¹	—	+	—	—
<i>C. tribuloides</i> Wahlenb. ^{1,2,3}	+	+	—	+
<i>C. trisperma</i> Dew. ^{1,2,3}	+	+	+	+
<i>C. tuckermanii</i> Dew. ^{1,3}	+	+	+	+
<i>C. umbellata</i> Willd. ^{1,2,3}	+	+	+	+
<i>C. vaginata</i> Tausch ^{1,2}	+	+	—	+
<i>C. vesicaria</i> L. ^{1,2,3}	+	+	+	+
<i>C. viridula</i> Michx. ^{1,2,3}	+	+	—	+
<i>C. vulpinoidea</i> Michx. ^{1,3}	+	+	+	—
<i>C. xerantica</i> Bailey ²	—	—	—	+
Total	70	91	66	60

¹Reported by Lakela (1965) for St. Louis Co. or Lake Co., or both.²Reported by Butters & Abbe (1953) for Cook Co.³Reported by Wheeler (1977) for Itasca Co.

The northern sugar maple-basswood-dominated forests, in spite of physiognomic resemblance to sugar maple-basswood forests in the southern portion of the state, differ mainly in that white pine and yellow birch are often important members of the community and the herb and shrub species are mostly different. For instance, three species of *Carex* that grow in the northern forests, *C. arctata*, *C. leptoneuria*, and *C. ormostachya*, are unknown in forests of the south; in turn, 13 species in southern forests are unknown in those of the north. Several species, including *C. pennsylvanica*, *C. rosea*, *C. sprengelii*, *C. communis*, *C. deweyana*, *C. gracillima*, *C. intumescens*, *C. peckii*, and *C. pedunculata*, are common to both northern and southern forests, the last six of which are clearly more widespread and more common northward. The northern and southern mesic forests of Wisconsin, in many respects similar to those of Minnesota, have been discussed by Curtis (1959).

Several predominantly southern and western Minnesota carices occur on favorable sites in the western portion of the study area (*C. bicknellii*, *C. crawei*, *C. tetanica*, and *C. torreyi* in St. Louis Co.; *C. brevior*, *C. prairea*, and *C. richardsonii* in St. Louis and Itasca Cos.), but they are unknown from the east (Lake and Cook Cos.). *C. crawei*, *C. tetanica*, and *C. prairea* grow in moist to wet, open places, whereas the remaining four species frequent drier sites. Of these seven carices, only *C. prairea* and *C. richardsonii* are of more than very uncommon occurrence. The single known station for *C. torreyi* in St. Louis Co. (sandy soil along railway near Payne, *Lakela* 21446) is one of the easternmost in North America; Zimmerman (1976) reported it from two counties in Wisconsin.

While several carices of St. Louis Co. are not known from Itasca Co. (Table 1), it is suspected that some of them will be found there on further investigation. Only one part of Itasca Co., the Grand Rapids-Cohasset area (Wheeler, 1977), has been well botanized. Indeed, some habitats, such as upland peatland, have been little studied in Itasca Co., whereas several upland peatlands have recently been studied in St. Louis and Lake Cos. (Glaser, unpubl.), resulting in new records for both counties.

Several carices are at or near the limits of their ranges in northeastern Minnesota. Four of them, *C. supina*, *C. xerantica*, *C. katahdinensis*, and *C. pallescens*, are of particular phytogeographic interest:

Carex supina is a circumpolar species that in North America occurs primarily in the far north, but disjunct populations are known in southeastern Manitoba and northeastern Minnesota (Hultén, 1964). In Minnesota this species is known from the talus of cliffs bordering Clearwater Lake in northern Cook Co., the southernmost station in North America (Butters & Abbe, 1953). It may be that *C. supina* was more common in the area during late-glacial times and that it is a relict of wider southern distribution in the past. However, its migration to favorable habitats after glaciation cannot be ruled out. The nunatak hypothesis of Fernald (1935) is no longer considered tenable (Cushing, 1965).

Carex xerantica is a plant of prairies and plains that reaches its easternmost limit in the state (Fernald, 1950; Gleason & Cronquist, 1963). It is a member of the Ovals "group" (Voss, 1972) and is distinguished by whitish or silvery spikes. In Minnesota this species is known from the tops of cliffs bordering

Watab Lake in northern Cook Co. (Butters & Abbe, 1953). It is not known from the prairies of western Minnesota, and thus its isolated presence in Cook Co. may indicate a more widespread occurrence during the xerothermic period. However, because the species is known from stations in North Dakota (McGregor et al., 1977) and Manitoba (Scoggan, 1957, 1978), recent migration to Minnesota is possible.

Both *C. katahdinensis* and *C. pallescens* are best known from far eastern Canada and the United States (Fernald, 1950) but also have populations farther west, with the westernmost in Minnesota (Lakela, 1965). The former is known from sandy beaches and shore rocks of Iron Lake, St. Louis Co., near the Ontario border (Lakela, 1952), and the latter from moist places on the Lake Superior terrace near Duluth, St. Louis Co. (Lakela, 1954).

Some authors (Boivin, 1967; Scoggan, 1978) consider *C. katahdinensis* to be a form of *C. conoidea*, as fo. *katahdinensis* (Fern.) Boivin; other authors (Mackenzie, 1931-35; Fernald, 1950; Gleason & Cronquist, 1963) treat them as separate species. Because in Minnesota these two taxa are well-marked, morphologically and ecologically, they are treated here as separate species. *Carex conoidea* is a plant of moist, grassy meadows with widely-separated lateral spikes and a long-peduncled terminal spike. Six stations are known in Minnesota, two of them in St. Louis Co. *Carex katahdinensis*, on the other hand, has congested lateral spikes and a sessile or subsessile terminal spike; all Minnesota specimens of this taxon in the University Herbarium are from Iron Lake.

Additions and Deletions

Although *C. exilis* has been previously reported from Minnesota (Wheeler & Glaser, 1979), it has only recently been discovered in the northeastern portion of the state. Work in the peatlands of northern Minnesota has shown this species to be an occasional constituent of patterned fens in Lake, St. Louis, Koochiching, and Beltrami Cos., with the Red Lake Peatland (Beltrami and Koochiching Cos.) having the westernmost known stations in North America (Wheeler & Glaser, 1979). In these patterned peatlands *C. exilis* is most abundant in narrow strips of open poor-fen ecotone separating ombrotrophic bogs from minerotrophic fens, but it also occurs on strings of patterned fens and more rarely in flarks. The plant is not known from ombrotrophic sites in these mires.

LAKE CO.: patterned fen, S of Cougar Lake, T59N, R11W, Sec. 34, *Glaser 1142*,
ST. LOUIS CO.: patterned fen, 2.5 mi. N of Albion on Rte. 7, T53N, R18W, Sec. 12, *Glaser 1055*; patterned fen, Lost Lake Swamp, 1.5 mi. NE of jct. of Rte. 1 and 476, T61N, R16W, Sec. 6, *Glaser 1092*.

Carex livida was reported from Cook Co. by Butters & Abbe (1953); it is uncommon there on wet highway verges and at borders of white cedar swamps. Although Butters & Abbe also reported the species from Lake Co. (*B. Juni*, 1878, MIN), Lakela (1965) did not include the species in her flora. Recently, *C. livida* has been found as a frequent constituent of peatlands throughout

northern Minnesota, in Lake, St. Louis, Koochiching, Lake of the Woods, Beltrami, and Roseau Cos. The plant is most common and abundant in flarks of patterned fens but also occurs in *Sphagnum* lawns and narrow ecotone strips between ombrotrophic bogs and minerotrophic fens. Although frequenting both rich- and poor-fen sites, *C. livida* is not known from ombrotrophic sites.

LAKE CO.: patterned fen, S of Cougar Lake, T59N, R11W, Sec. 34, *Glaser 1141*. ST. LOUIS CO.: patterned fen, 2.5 mi. N of Alborn on Rte. 7, T53N, R18W, Sec. 12, *Glaser 1051*; patterned fen, Lost Lake Swamp, 1.5 mi. NE of jct. of Rte. 1 and 476, T61N, R16W, Sec. 6, *Glaser 1091*; patterned fen, 0.05 mi. SE of Rte. 351, just NE of Mud Lake, T55N, R15W, Sec. 4, *Glaser 1138*; patterned fen, 7 mi. W of Forbes on Rte. 16, T57N, R19W, Sec. 33, *Glaser 1132*; patterned fen, 1.5 mi. E of Nichols Lake on Rte. 232, T53N, R17W, Sec. 16, *Glaser 1124*; wet meadow, N edge of Hornby Lake, T56N, R12W, Sec. 8, *Glaser 1109*; patterned fen, 10 mi. E of Babbitt, T60N, R12W, Sec. 13, *Glaser 1101*.

Carex praticola has been reported from Cook Co. (Butters & Abbe, 1953), from the tops of cliffs bordering Clearwater, Mountain, and Watab Lakes in the Rove Slate area near the Ontario border. It has recently been discovered in Lake Co.

LAKE CO.: sandy soil, Lake Isabella area, T62N, R8W, *Lindstrom*, June 30, 1979.

Five carices of Cook County not reported by Butters & Abbe (1953) follow:

Carex arcta. Woods, island on W side of South Fowl Lake, T64N, R3E, *Butters, Abbe & Burns 636* collected in 1940, identified in recent years by Dr. John Moore. *C. bebbii*. Roadside, 0.5 mi. E of Grand Portage, T63N, R6E, *Benner 491*. *C. chordorrhiza*. Patterned fen, 1 mi. N of Grand Marais, T61N, R1E, *Glaser 973*. *C. flava*. Swampy roadside, SE of Schroeder on Rte. 61, T58N, R5W, *Lakela 6430*. *C. tuckermanii*. Wet depression at roadside, T62N, R4E, Sec. 6, *Morley 1404*.

Re-examination of material collected by Lakela has resulted in the following seven additions from St. Louis and Lake Cos. (More recent collections are also included.)

C. bicknellii. ST. LOUIS CO.: open hillside adjoining Enger golf course, Duluth, *Lakela 5079* (cited in her flora as *C. merritt-fernaldii*).

C. cephalantha. LAKE CO.: shore rocks of Lake Superior, near mouth of Knife River, *Lakela 4494*. ST. LOUIS CO.: wet meadow, St. Louis Bay, near Duluth, *Lakela 1488*; border of small lake, 18 mi. N of Duluth on Rte. 53, *Lakela 3058*; wet meadow bordering Sand Lake on Rte. 53, *Lakela 3846*; floating bog, Dark Lake, *Lakela 17740*; floating bog, W end of Burntside Lake, near Ely, *Lakela 17855*; floating bog, small lake S of Pelican Lake on Rte. 23, near Orr, *Lakela 20018*; wet depression, spruce-tamarack forest, S of Silica on Rte. 73, *Lakela 20428*. (Nos. 1488, 4494, 3846, 20018, 20428 originally as *C. laricina*; 3058 as *C. interior*; 17740 and 17855 as *C. cephalantha*, which was not included in Lakela's flora.)

C. emoryi. ST. LOUIS CO.: river bank, Savanna River, near floodwood, *Lakela 10974* (cited as *C. vesicaria*); sandy beach ("Loon Flats"), Little Vermillion River,

Ontario boundary, *Lakela* 12823; waters edge, Willow River, S of Greaney, *Lakela* 20062. (No. 12823 originally as *C. strictior*; 20062 as *C. aquatilis* var. *altior*.)

C. garberi. ST. LOUIS CO.: swampy area near Rte. 53, 1 mi. N of Cotton, T54N, R17W, *Lakela* 6888 (originally as *C. aurea*).

C. gynandra. LAKE CO.: edge of small creek, 0.25 mi. S of Silver Bay taconite plant on Rte. 61, *Wheeler c-67*; jct. of Rte. 61 and Encampment River, *Lakela* 4069. ST. LOUIS CO.: meadow, French River district (Smith Road), *Lakela* 11262; trail to Front Lake, Kabetogama Peninsula, *Moyle* 2606. (*Lakela* 4069, 11262, and *Moyle* 2606 originally as *C. crinita*.)

C. praegracilis. LAKE CO.: Castle Danger, shore of Lake Superior, *Breckenridge* and *Nielsen* 3182; meadow, Franklin, Barrows 53; wet sand, Interstate Bridge area, Duluth, *Lakela* 3980. (*Barrows* 53 originally as *C. prairea*; *Lakela* 3980 as *C. diandra*.)

C. tetanica. ST. LOUIS CO.: moist, open field adjacent to Chester Park School, Duluth, *Lakela* 5323. (This specimen was correctly identified, but the species was not included in *Lakela*'s flora.)

Carex garberi is best known from the Great Lakes region, where it grows on sandy beaches and rocky shores (Fernald, 1935, 1950). Although well known from Michigan (Voss, 1972), it is uncommon or rare in Indiana (Hermann, 1940), Illinois (Mohlenbrock & Ladd, 1978), and Wisconsin (Read, 1976; Zimmerman, 1976). The site near Cotton is the only known station for *C. garberi* in Minnesota; this is the first report of the species from the state.

Some authors (Fernald, 1950; Gleason & Cronquist, 1963; Scoggan, 1978) consider *C. gynandra* a variety of *C. crinita*, as var. *gynandra* (Schwein.) Schwein. & Torr., but others (Mackenzie, 1931-1935; Voss, 1972) treat them as separate species. In Minnesota, Wisconsin (material recently examined by the author), and Michigan (Voss, 1972), the taxa are well-marked and easily distinguished. In Minnesota *C. gynandra* is restricted to the northeastern counties, where it is infrequent to occasional along banks of streams and in wet openings (Wheeler, 1981). *Carex crinita*, on the other hand, occurs throughout most of the eastern half of the state and is frequent in wet woodlands and at borders of rivers and ponds.

Carex praegracilis has recently been reported as an aggressive adventive in Ontario and Michigan (Reznicek et al., 1976). Although native in western and south-central Minnesota, it appears to be adventive in the north-central, north-eastern, and extreme east-central portions of the state. In northeastern Minnesota it has been found along the shore of Lake Superior in disturbed sites; in east-central Minnesota it is established on some highway verges. In the western half of the state the plant is widespread in prairie swales and other wet depressions, but it becomes progressively more infrequent eastward. The native distribution of *C. praegracilis* in Minnesota approximates that of calcareous drift deposited by the Mankato Substage of the Wisconsin Stage of glaciation; its abrupt absence from southeastern Minnesota is more than likely owing to a lack of low, wet, strongly calcareous habitats in an area not invaded by the Des Moines Lobe of the Mankato Substage.

As stated above, some carices should be deleted from Lakela's list for Lake and St. Louis counties. *Carex molesta* is occasional to frequent in the southern half of Minnesota, but no verified records exist for it north of a line from Isanti Co. to northern Douglas Co. The plants called *C. molesta* by Lakela (Lakela 10767 & 14581) are assignable to *C. brevior*. Some records of *C. normalis* are known from the northern half of the state (Clearwater and Morrison Cos.), but none exist for the four counties under consideration. The plants called *C. normalis* by Lakela (Lakela 8835, 10840, 11719a) are assignable to *C. tenera*. Although Lakela reported *C. strictior* and *C. laricina* from northeastern Minnesota, in accord with recent authors (Fernald, 1950; Voss, 1972; Zimmerman, 1976) I do not treat the former distinct from *C. stricta* or the latter distinct from *C. cephalantha*.

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PUBLICATIONS OF INTEREST

ATLAS OF UNITED STATES TREES Volume 6, Supplement. By Elbert L. Little, Jr. U. S. Dept. of Agriculture Forest Service Misc. Publ. 1410. 1981. \$3.00 (U. S. Government Printing Office). This volume concludes Little's monumental survey of the distribution of U. S. trees (see review, *Mich. Bot.* 19: 46, 1980). It includes summary information and statistics, changes in names to conform to Little's 1979 checklist, maps for 35 species of *Crataegus* (using essentially the concepts of Cronquist) of which 12 are shown in Michigan, one additional juniper from the West, and cumulative indexes to common and scientific names in the 6 volumes. The *Crataegus* maps have only a dot in each state (sometimes one in each peninsula of Michigan).

THE VASCULAR PLANTS OF UNGLACIATED OHIO. By Allison W. Cusick and Gene M. Silberhorn. Ohio Biological Survey Bull. Vol. 5 No. 4. 1977. x + 153 pp. \$9.00 [+ \$.90 postage (+ 4½% sales tax in Ohio), from the Survey, 484 W. 12th Ave., Columbus, Ohio 43210]. Appropriately dedicated, with portrait, to the memory of Floyd Bartley, "Ohio's most famous twentieth century amateur botanist," this publication includes an annotated list of 2071 species and hybrids of vascular plants from southern and eastern Ohio. Introductory material briefly surveys the climate, bedrock geology, physiography, vegetational history, and plant communities of the region, which comprises all or portions of 33 Ohio counties. County records and further details for rarities are given in this up-to-date production.

THE OHIO COUNTRY FROM 1750 TO 1977—A NATURALIST'S VIEW. By Milton B. Trautman. Ohio Biological Survey Biol. Notes 10. 1977. 25 pp. \$2.50 [+ \$.25 postage (+ 4½% sales tax in Ohio), address above]. Based on the author's lecture, "The Ohio That Was," this publication notes, with appropriate documentation, changes in the condition of the land, in water use and quality, and in populations of animals. A readable and philosophical account, which could be paralleled in neighboring states.

25 THE BLUE SAILOR: WEED OF MANY USES [J]

n
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From late June through early fall a prominent element of color in the Michigan roadside landscape is a plant variously called the blue sailor, blue daisy, succory, and chicory. Viewed from a distance, the masses of blue bloom enhance the beauty of the landscape. The individual chicory plant with its straggly stems, however, is hardly prized as a garden object, even though the ephemeral flower in itself is not unattractive. While well-known as a cosmopolitan weed, chicory also exists in the form of cultivated varieties which are of considerable economic value. For many years chicory was grown in Michigan as a companion crop to sugar beets. It is a species which has been largely ignored by botanists as an object for research even though it presents a number of problems which should be of theoretical interest to biologists.



Cichorium intybus, a member of the composite family, is a perennial which forms a rosette of oblong to lanceolate, irregularly toothed leaves on the crown of a sturdy tap root. As the season progresses, a stem develops, generally reaching a height of two or three feet. The upper part of the stem is leafless, or, when leaves do form, they are small and clasping. The leafless character of the stem gives the plant its straggly appearance. The flower heads are produced in loose clusters at the upper nodes of the stem. Only one flower head of a cluster blooms at a time, opening in the early morning and closing by noon, or somewhat later if the day is overcast. Each head is composed of only one kind of floret with a pale blue strap-like corolla, the tip of which is toothed. Each floret bears five stamens and an ovary which develops into a single-seeded fruit. An occasional plant may bear heads with white or pink florets.

Chicory is native to the eastern Mediterranean region, an important center of origin for many weeds as well as cultivated species. The ancient Greeks recognized that chicory was of some value; Aristophanes mentioned chicory in discussing the preparation of wild vegetables, and in his *Materia Medica*, Dioscorides attributed medicinal properties to it. Belief in its medicinal value has persisted throughout history and chicory is still listed today as a tonic and diuretic. Chicory was regularly included in the herbals which were the primary source of information (and often, misinformation) about plants during the Middle Ages. Benefits ranging from the amelioration of toothache, the improvement of digestion, and the purification of blood were attributed to the plant. Recipes were given for the preservation of the roots and for the concoction of various syrups and essences for medicinal use.

During the 16th century, the product of another plant, coffee, came into general use in Europe and was to have an impact upon the utilization of chicory. Coffee drinking originated in the Mideast and by 1630 had become popular in Constantinople. From there, the custom soon spread to Europe; the earliest known introduction of coffee into Germany was in 1637. A Lebanese opened the first coffee house in England in 1650. It is interesting to note that in 1592, Prosper Alpino, Professor of Botany at the University of Padua (Italy), pointed out that coffee tasted very much like a concoction of chicory! This implies that chicory was in common use at the time, probably as a medicinal beverage. As coffee houses became popular, they served increasingly as centers of social and intellectual interchange. King Charles of England considered the coffee houses a seditious threat and would have liked to have them closed. However, he did not wish to risk the danger of public protest that such interference with a basic human right might elicit. As an alternative, the Crown set a high tax on the coffee drink when it was sold publicly. The taxation of coffee was one factor that led to the introduction of coffee substitutes and adulterants.

In spite of the apparent common use of chicory as a medicinal herb, a true "coffee" prepared from chicory was not discovered and marketed until the 18th century. The commercial production of chicory for use as a coffee substitute is reputed to have come about in the following way. During the Seven Years War (1756-63) the wife of a German army officer was attacked and raped by French soldiers. As a result of this incident, she fell ill with a fever and appeared to be wasting away. A physician prescribed boiled chicory roots and a

chicory tea for her, and while the treatment improved her condition, she found it so distasteful that she experimented with roasting the root before using it. She developed a method for producing a quite palatable drink. Her husband and a friend decided to market this chicory "coffee." They took their preparation to the owner of the only coffee house in the region; when the latter discovered that the price was only half that of real coffee and that it could be used as an adulterant without his customers detecting it, he willingly bought the chicory. Subsequently, the producers applied to Frederick the Great for a license to prepare and sell chicory coffee in Prussia. During the same period, commercial chicory coffee production began in France.

In 1778 Frederick the Great established regulations for the sale of coffee; he believed that coffee was not a necessity for ordinary people. The nobility, however, were excluded from these regulations. Subsequently, he also placed a heavy tax on coffee, the effect of which was to stimulate the use of coffee substitutes, particularly chicory. Then in 1806 Napoleon, who at the time not only ruled France, but occupied Prussia, placed an embargo on all trade with England. As a result, coffee became scarce and its price increased; the chicory industry was again stimulated. Still wider use of chicory came in 1850 when the Prussian High Command replaced the ration of whisky with one of coffee. The war of 1870-71 further encouraged the production of chicory.

The widespread use of chicory as an adulterant or a substitute for coffee brought about a preference for it; at the present time, a mixture of 2 or 3 parts of coffee to 1 of chicory is often favored over pure coffee in France and Belgium.

Chicory was apparently first introduced into America by Governor Bowdoin of Massachusetts in 1785, who considered it a desirable salad green. The plant was later cultivated to a limited extent, but attempts to grow it as a farm crop did not come until the 1890's. However, there was a market for chicory in this country earlier, since records from the U. S. Treasury Dept. show that, for example in 1869, almost 3 and 1/2 million pounds of chicory were imported from Europe. Surprisingly, in the latter part of the 19th century, coffee adulterated with chicory, as well as with other substances, sold well in the United States. For example, in 1876 a typical product that was marketed as genuine coffee was actually a mixture made from roasted peas, rye, chicory, and coffee, with the latter constituting only about one quarter of the total mix.

Chicory was still being grown as a field crop in the 1940's in the Saginaw Valley and Thumb areas of Michigan, but by 1961 domestically produced chicory was apparently no longer competitive with the imported product. Currently only some 250 acres or less are being planted to chicory in the United States. One grower in California who operated his own processing facilities and marketed the chicory directly found it unprofitable to produce a crop in 1981. The profitability depends on the world price as well as the return on other crops to which the acreage may be planted. Another grower in Florida was encouraged to provide a domestic supply of chicory by one of the major coffee marketing firms promoting a coffee blend containing chicory. The firm subsequently bought out a European producer and lost interest in the U.S. grown product. Presently, most chicory is grown in Europe with France, Belgium, Hungary,

Poland, and the Soviet Union the leading producers. Outside of Europe, South Africa is the only country planting acreages comparable in size to those of the European producers.

The cultural methods suitable for chicory production are essentially the same as those utilized for growing sugar beets; thus, chicory is commonly grown as a companion crop to sugar beets and this accounts for its earlier culture in Michigan. Rotation of chicory with sugar beets is desirable because it reduces infestations in the soil of nematodes attacking sugar beets.

Chicory is especially well suited to moderately clayey or clayey sand soils. The crop is planted in the spring as soon as the ground can be worked but not before the danger of frost is over. Pelletized seed is used and planted with the same machinery employed for seeding sugar beets. Although chicory is drought resistant during its later development, adequate moisture is necessary for germination and early seedling growth. Weeds are controlled by herbicides; chicory is relatively pest free except for wire worms and the larvae of the May beetle which feed on the roots. These are controlled by chemical means. The crop requires 160 to 180 days to mature. Equipment utilized for sugar beets serves for the harvesting operations. The plants are first topped and the green matter used either for forage or green manure. The roots are then dug. Yields range from 34 to 40 metric tons per hectare (2.471 acres). The general practice is for the marketer to contract with a grower to plant a specific acreage at a guaranteed price. The grower is furnished the seed, herbicides, and insecticides.

After being dug, the chicory root is washed, sliced into chunks about the size of an egg, and placed in a drier. Thorough drying of the root allows it to be stored more or less indefinitely without a deterioration of its quality. The dry root is roasted in drums under controlled temperatures and then ground. The product has been marketed in a powder, in granulated form, or in tablets. The granulated chicory goes to coffee roasters for use in blending. In the United States, chicory has been included in all coffee blends in the New Orleans area since before the Civil War. Recently, when coffee prices skyrocketed, a chicory-blended coffee was introduced for national marketing by one of the major producers and is now regularly available in the supermarkets.

Chicory is also utilized in the food industry. The powdered form is used to flavor dark rye or pumpernickel bread and is added as a seasoning to soups, sauces, and gravies; it intensifies the flavor of meat and vegetables and improves the taste of cakes and cookies made with chocolate. The bitter-sweet quality of the chicory root comes from the combination of the bitter principle, taraxacine, also found in the dandelion, with the natural sugars which become caramelized through the roasting. The chicory root contains inulin, a type of starch composed of the sugar, fructose.

Our discussion until now has centered on chicory as a coffee adulterant or substitute. However, *Cichorium intybus* also includes varieties which are economically important as a salad green or pot herb variously known as witloof chicory, barbe de capuchin, and French or Belgian endive. These are seeded in May or June; in the late fall, the tops are removed and the roots dug. The roots are then induced to sprout by several different methods. For example, the roots may be placed horizontally in tiers in a pile of moist soil so that the crown of

each root projects from the sloping heap of soil. Such heaps are constructed in a cellar where they can be kept dark. The crowns sprout in 3 to 4 weeks and are then ready for harvest. The same crowns may produce additional crops.

In another method, a bed is tilled and the roots set with the crown at or just below the soil surface. The bed is then covered with an 8 to 10 inch layer of sand and a topping of manure to generate heat. The roots are dug in order to harvest the crop of sprouts; the roots may then be fed to livestock.

A feasible method of growing witloof chicory sprouts at home is simply to place the roots in boxes, leaving the crowns uncovered. The boxes are moved to a warm dark cellar where the shoots will sprout and can be harvested in 3 or 4 weeks.

The home gardener or natural foods enthusiast can grow and process chicory roots for use as a coffee substitute or food additive using garden and kitchen facilities. Mature roots can be used to produce sprouts or the roots can be harvested when young, and if boiled and prepared like carrots are a tasty vegetable. Those who intend to grow chicory in the home garden should be reminded to select the cultivated variety appropriate for the intended use.

As we drive through the countryside catching glimpses of the blue sailor at the edge of the road, it is well to remember that this species is not merely a weed, but an economic plant which has had some influence on the political, social, and economic history of man since ancient times.

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PUBLICATIONS OF INTEREST

- A SYNONYMIZED CHECKLIST OF THE VASCULAR FLORA OF THE UNITED STATES, CANADA, AND GREENLAND. By John T. Kartesz & Rosemarie Kartesz. Univ. North Carolina Press, Chapel Hill. 1980. xlviii + 498 pp. \$35.00. This checklist includes "some 22,000 species of vascular plants in 255 families" accepted by the compilers and their "reviewers and cooperating specialists" (of which there are none for many groups). Families, genera, species, and subspecies are alphabetical, with synonyms (both taxonomic and nomenclatural) alphabetical under each. As synonyms are not themselves included in the alphabetical listings, with cross references to accepted names, nor are they in the index (which covers families and genera), it may be very difficult to locate the disposition of them. *Panicum spretum*, for example, is legally a "threatened species" in Michigan but can be found in this checklist only as a synonym (of unstated nature) under *Dichanthelium acuminatum* var. *densiflorum*. The work will not therefore be very useful to many editors, conservationists, and others little experienced in tracking down synonyms but curious about what this list calls certain species. But for those who want a fairly up-to-date accounting of opinions on what taxa occur in North America north of Mexico plus Hawaii and Greenland, this is a quite well done volume. (For a longer review, see Syst. Bot. 6: 91-93. 1981.)

PLANTAE VASCULARES URSS. By S. K. Czerepanov. "Nauka," Leningrad. 1981. 509 pp. 7R 20K. Except for an alternative title page and two pages of preface in Russian, this checklist of the vascular plants of a large portion of the northern hemisphere is (like the list noted above) essentially in Latin. There are very brief annotations in Russian for some of the names. Arranged alphabetically by the accepted names for families, genera, and species, with no dates or bibliographical citations, the volume is similar to the recent Kartesz and Kartesz checklist, which covers much of the rest of the northern hemisphere. However, in addition to indicating major synonyms for accepted names, this one also includes them in alphabetical order with cross-references. There is an alphabetical index to names of families and genera. The nomenclature and author citations seem very much up to date. This volume will be useful to all who want the latest opinion on the numbers of taxa in the Soviet Union and the names for them. It is a flora remarkably similar in size to that covered in the list cited above, with 21,463 species, more than 330 subspecies, and some 445 hybrids, in 1,977 genera and 211 families. The price is about \$11.00 at the official rate of exchange, and only 3350 copies were printed.

REVIEW

FLOWERING PLANTS: BASSWOODS TO SPURGES. The Illustrated Flora of Illinois. By Robert H. Mohlenbrock. Southern Illinois University Press, Carbondale. 1982. 234 pp. \$22.95.

This latest volume (the 10th in its series) covers the orders Malvales, Urticales, Rhamnales, and Euphorbiales as defined in Thorne's system—103 species in all. General observations have appeared in reviews of previous volumes (e.g., Mich. Bot. 20: 180; 21: 116). The illustrations (all by Mark Mohlenbrock) are quite good; the keys are in excellent contrasting style and more or less original but with very few characters used (so one dearly hopes to see those chosen!). It is distressing to see disagreements of subject with verb ("Urticales is"; "Euphorbiaceae is"), slips like "Elaeagnaceae" and *Abutilon* "*theophrastii*," the abbreviated name of Linnaeus in a different size and style of type than that for all other authors of generic names, and *Euphorbia commutata* said to have cyathia up to 32.5 mm in length and finely pitted fruits.

No reason is stated for not accepting Brizicky's conclusion (cited) that *Ceanothus herbaceus* is the correct name for "*C. ovatus*." No hint is given that *Celtis tenuifolia* ranges anywhere near southern Michigan and Ontario. *Malva houghtonii* was recorded from Illinois not only by the authors cited but also in the original description. Although recognition of *Poinsettia* and *Chamaesyce* as genera distinct from *Euphorbia* is a matter of taste in which the author is in good company, it is misleading to say that "now" it has been discovered that *Euphorbia maculata* applies to the species previously known as *E. preslii*. (While Wheeler held that position, and was widely but not universally followed for about 25 years, since Burch's exposition in 1966, usage has been almost universal in restoring that name to the prostrate plant known for a while as *E. supina*—e.g., recent checklists for North America and the U.S.S.R., Flora Europaea, and a number of local floras. The present volume does not even list as a synonym the widely used name *E. nutans*, which replaces *E. maculata* for the erect plant, and thus it only prolongs the confusion.)

If Mohlenbrock has seen "reddish" fruit on *Dirca palustris* in the field, it is worthy of note, contradicting numerous field observations in Michigan, Indiana (by Deam), New York, and elsewhere (cf. Asa Gray Bull. n. s. 2: 81–82. 1953). And I cannot believe that *Shepherdia* blooms in northern Illinois "May to July" when for the same counties Swink indicated April and for adjacent Indiana Deam noted that it bloomed before all other shrubs, citing only March.

I note that five species are mapped from every county in Illinois—a tribute to the assiduity of collectors in that state!

—E. G. Voss

245 SPERGULARIA (CARYOPHYLLACEAE) IN OHIO []

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Spergularia is a cosmopolitan genus of low annual or perennial herbs usually known as sand-spurreys. Three species occur in Ohio, none indigenous: *S. marina* and *S. media* are succulent halophytes of recent introduction, and *S. rubra* is a local garden weed long established in the state. This survey describes the Ohio distribution of the genus and the rapid advance in the state of the halophytic sand-spurreys. Taxonomic treatment and general geographic information are taken mainly from Gleason & Cronquist (1962), Fernald (1950), and Rossbach (1940). Specimens examined are housed at CLM, BGSU, BHO, KE, MU, and OS. The numbers on the distribution maps are the last two digits of the year of the first twentieth century collection in the county so indicated. Dates for nineteenth century collections are given entire.

SPERGULARIA MARINA (L.) Griseb. (Fig. 1)

This is an annual fleshy halophyte of nearly world-wide distribution. In the United States it is known chiefly from coastal regions, with only scattered stations in the interior. In the Great Lakes area, it has been reported from Michigan, New York, and Ontario (Catling & McKay, 1981; Reznicek, 1980). There are no reports for Indiana, Pennsylvania (Deam, 1940; Wherry et al., 1979), or Ohio (Weishaupt, 1971).

Spergularia marina was first collected in Ohio in 1971 from a road berm in Wayne County (Cusick & Wilson 2257, KE 26023). All known specimens are from highway verges except one from the vicinity of brine wells, also in Wayne



FIG. 1. The Ohio distribution of *Spergularia marina*. Double digits refer to collections in 1971, 77, 80. FIG. 2. The Ohio distribution of *Spergularia media*. The numbers refer to collections in 1977, 79, 80. FIG. 3. The Ohio distribution of *Spergularia rubra*. The numbers refer to collections in 1885, 73, 79.

Co. (Riehl & Ungar, 1980). This last collection illustrates the sudden appearance of this species in disturbed sites. *S. marina* was not listed by Cusick in his report of this brine well field (1970), nor was it observed by this writer at that site from 1970 to 1975. Riehl and Ungar first noted *S. marina* in 1978 but had not found it in the well field before that year.

Habitat and ecological requirements for *S. marina* are essentially the same as for *S. media* and are discussed under that species.

SPERGULARIA MEDIA (L.) C. Presl ex Griseb. (Fig. 2)

This European native has been reported variously as an annual, biennial, or short-lived perennial. It is a fleshy halophyte similar to *S. marina* and, in Ohio at least, occasionally occurs with that species. *S. media* is known from the Pacific coasts of North and South America and from central and coastal New York. Elsewhere it is very local. In the interior United States it has been reported only from Indiana (Gunn, 1974), Michigan (Reznicek, 1980), and Illinois (Henry & Scott, 1981; Mohlenbrock, 1975). It is not listed for Ohio by Weishaupt (1971).

The first Ohio collection of *S. media* was in 1977 from a road berm in Medina County (Cusick 16852, KE 39084). It is now locally abundant along heavily salted highways in 10 scattered counties. Eventually it may be found in all sections of the state. It is ironic that *S. media*, the most recently collected sand-spurrey in Ohio, is also the *Spergularia* most widely distributed in the state.

Both *S. marina* and *S. media* occupy a zone of vegetation adjacent to the paved road surface. They are especially common along major routes, such as interstates, to which de-icing salt has been applied repeatedly. The verges are not saline at first, of course, but through time salt accumulates until a concentration is reached at which most vegetation cannot survive. *S. marina* and *S. media* invade these barren, saline situations and flourish. Frequent associates of *S. marina* and *S. media* in this verge habitat are *Anagallis arvensis*, *Carex praegracilis*, *Hordeum jubatum*, and *Puccinellia distans*.

SPERGULARIA RUBRA (L.) J. & C. Presl (Fig. 3)

In contrast to the preceding species, *S. rubra* is an annual garden weed which is only barely succulent and is not found in saline environments. Although Fernald (1950) indicates that it may be indigenous "about Gulf of St. Lawrence," it is more likely naturalized from Europe. It occurs sporadically across the continent from Newfoundland to British Columbia, south to the Gulf and Pacific coasts. Among states bordering Ohio, *S. rubra* has been reported only from Indiana (Deam, 1940) and Michigan (Beal, 1905; Farwell, 1923). Weishaupt (1971) lists this species for Ohio but omits the asterisk marking non-indigenous species.

The earliest Ohio collection of *S. rubra* is from Lake County in 1885 (Werner s.n., OS 17384). All collections are from gardens, flowerbeds, or freshly disturbed earth, none from roadsides.

It is instructive to compare the rarity of *S. rubra* with the rapid advance of *S. marina* and *S. media*. *S. rubra* occupies a generalized habitat in which it must compete with numerous other weeds. The halophytic sand-spurreys grow

in a specialized saline environment of very recent origin where there are few competitors and no long-established species. *S. rubra* may never become an important weed species in Ohio, but *S. marina* and *S. media* should continue to expand their ranges throughout the state. This expansion probably will be related directly to the continued use of de-icing salt and thus the creation of additional habitats for these species. *S. marina* and *S. media* may well become significant members of the spontaneous vascular flora of Ohio and, possibly, the entire Midwest.

I thank the curators of the herbaria listed above for courtesy and assistance. My research was supported by the Ohio Dept. of Natural Resources, Div. of Natural Areas and Preserves.

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REVIEW

SHRUBS OF ONTARIO. By James H. Soper & Margaret L. Heimbürger. Royal Ontario Museum Life Sciences Misc. Publ., Toronto, Ont., M5S 2C6. 2982. \$20.00 (CAN.)

Soper and Heimbürger present botanists and naturalists with a long awaited and useful book. A few points noted below aside, this book is a fine work and a must for anyone interested in shrubs in Ontario and the Great Lakes region.

The introduction explains scientific names and authorities, discusses shrub distribution, presents phytogeographic groupings of shrubs, and lists rare and endangered species. Keys to genera and distinctive species are provided at the beginning, and each genus of two or more species has a key. The keys look original and workable. About 210 species are treated in detail, with descriptions, dot distribution maps for Ontario, habitat notes and a "field check"—a list of distinctive characteristics for use in the field. The shrubs are arranged alphabetically within genera, and genera are arranged following Gray's Manual. The glossary at the end of the book is usually accurate, although the definition of an umbel as an inflorescence shaped like an open umbrella inverted by the wind is certainly unique. Treatments of *Amelanchier*, *Crataegus* and *Rubus* are conservative, and most plants should fit fairly easily into one of Soper and Heimbürger's broadly defined species. In all cases, there are references to more detailed or divergent treatments (although A. J. Breitung's Key to the genus *Rubus* of the Ottawa Valley, Can. Field-Nat. 66: 108–110. 1952, is not cited). The descriptions, habitat notes, and field checks for the shrubs reflect the authors' familiarity with the species in the field. The distribution maps are very complete, and the drawings, by Leslie Garay and Ronald With, are excellent.

There are a few inconsistencies in depth of treatment. Except for *Rhododendron canadense*, species known from only a single site are not mapped. However, some of them, including *Oplapanax horridum*, *Phyllodoce caerulea*, and *Myrica pensylvanica*, are treated in detail, whereas others, including *Dryas drummondii* and *Chimaphila maculata*, are merely mentioned under similar species. *Ledum decumbens* and *Andromeda polifolia*, also not treated in detail, are mapped from several sites, and *Parthenocissus quinquefolia*, presumably at least partly native, is neither mapped nor treated in detail.

Perhaps the weakest point of this book is the general lack of detailed treatments of introduced species. Only 14 introduced species are treated in depth and mapped. About 15 other introduced species are mentioned briefly but not keyed, and a number of species are noted as sometimes cultivated. Unfortunately, a large number of more or less rare introductions and some more frequent ones are not even mentioned as escaped. Among the more notable are *Syringa vulgaris*, *Prunus mahaleb*, *Salix caprea*, *Euonymus europaeus*, *Rosa multiflora*, *Berberis thunbergii*, *Prunus padus*, and *Amorpha fruticosa*, all known from more than one site in Ontario and some locally common. People using this book near cities are especially likely to be frequently frustrated.

Rather odd is the amount of waste space. For example, the description of the genus *Prunus* occupies 1/4 of page 200, the rest blank; the key to species occupies 1/2 of page 201, the rest blank; page 202 is a full page figure but then 1/2 of page 203 is occupied by the treatment of *Prunus americana* and the rest is blank except for the small map in the lower right corner. Large sections of the book are laid out in this manner. However, some parts of the book do have all these sections run together. Many pages could have been saved by a more efficient and consistent layout. Although typeset, the text is not right-justified, and this might also have saved space.

The book has very few typographical and other errors and appears sturdily bound—sewn in signatures and glued—with a water-resistant paper cover. At \$20.00 (Canadian) for 495 pages, the book is a good deal and well worth owning.

—A. A. Reznicek

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A NOTE ON THE CYTOTAXONOMY OF THE
GENUS *Salvia* IN CANADA []

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The genus *Salvia* is composed of 700 species (Willis & Airy Shaw, 1973) of annual or perennial herbs or shrubs distributed in tropical and temperate regions of the Old and New Worlds. It is characterized by a tubular or campanulate 2-lipped calyx (Fig. 3) and a lever-like process formed by a prolongation of the connective. Base chromosome numbers are 6, 7, 8, 9, 10, 11, 13, 17, 19 (Gill, 1971). There are no native species in Canada, but four aliens have been recorded; only one (*S. nemorosa*) has been naturalized. The purpose of this note is to put on record the chromosome number, reproductive biology, and distributional status of the genus in Canada.

Material was brought into cultivation by transplanting rootstocks or growing from seeds. The techniques have been discussed earlier (Gill, 1971, 1977, 1979). Vouchers are preserved in the herbarium of the University of Waterloo, where the work was done.

S. nemorosa L. (*S. sylvestris* Rydb.) Hespler, Ontario. The haploid count of 7 (Fig. 1) agrees with a previous report of $2n=14$, (Fedorov, 1969). Meiosis and pollen formation are normal, with 100% filled pollen. The plants are self-incompatible; no seeds were set in bagged inflorescences. Under open pollination usually only one to two seeds per calyx were counted. In nature, the flowers are freely visited by insects which presumably bring about pollination. The single population studied showed little variation in nature or under cultivation.

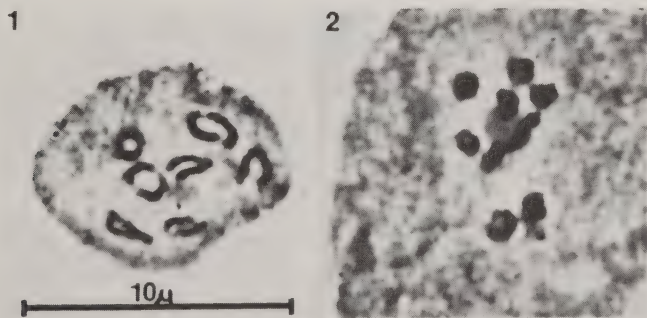


FIG. 1. *Salvia nemorosa*, $n = 7$. FIG. 2. *S. pratensis*, $n = 9$.

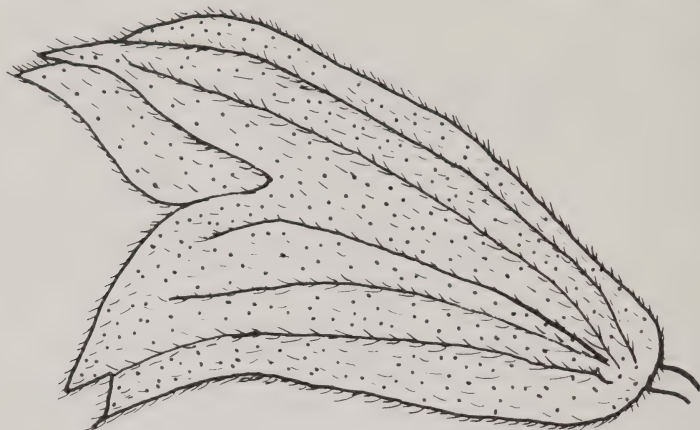


FIG. 3. Calyx of *S. nemorosa*, $\times 6$.

Native of Europe and introduced into Canada, this species was first observed in 1916 by A. Laidlow in Peel Co., Ontario, in his alfalfa field (White, 1917). It is locally established in dry, gravelly pastures, open fields, and river flats in southern Ontario, Manitoba, Alberta, and British Columbia (Fig. 4). Hitchcock et al. (1959) did not record the species for British Columbia, but collections exist from three localities there. Near Hespler, Ontario, it is locally abundant as the dominant ground cover, flowering from June to September.

S. pratensis L. Native of Europe and occasionally cultivated as a garden decorative, this species is represented in Canada by two Ontario collections: Hamilton, *Tamsalu* (HAM 4948); Tobermory, *Calvert* 5281 (UOW). There is no indication of whether the plants grew wild or cultivated. I have not examined living material of Canadian origin, but plants grown from seed supplied by the Park Seed Co. of South Carolina had a haploid number of 9 (Fig. 2). Meiosis and pollen fertility were normal.

S. reflexa Hornem is a native of the United States and extends from Ohio to Montana and southward to Arizona and Mexico. Sometimes cultivated and occasionally becoming temporarily established in dry, gravelly hay fields, pastures, and sides of roads and railways, it has been collected in a few scattered localities in Canada (Fig. 5). I have not studied living material from Canada.

S. verticillata L., a native of Eurasia introduced as an ornamental, is reported from three localities (Fig. 5) in southwestern Ontario: Markdale, Grey Co., *Montgomery* 1865; Harington, Frontenac Co., Brown (UOW 17412); Snelgrove, Peel Co. *Montgomery* (1957) remarked that if the species is allowed to spread in sandy areas, it may become a very serious weed pest. However, the plant does not persist in the above-mentioned localities. I have not examined living material from Canadian sources.

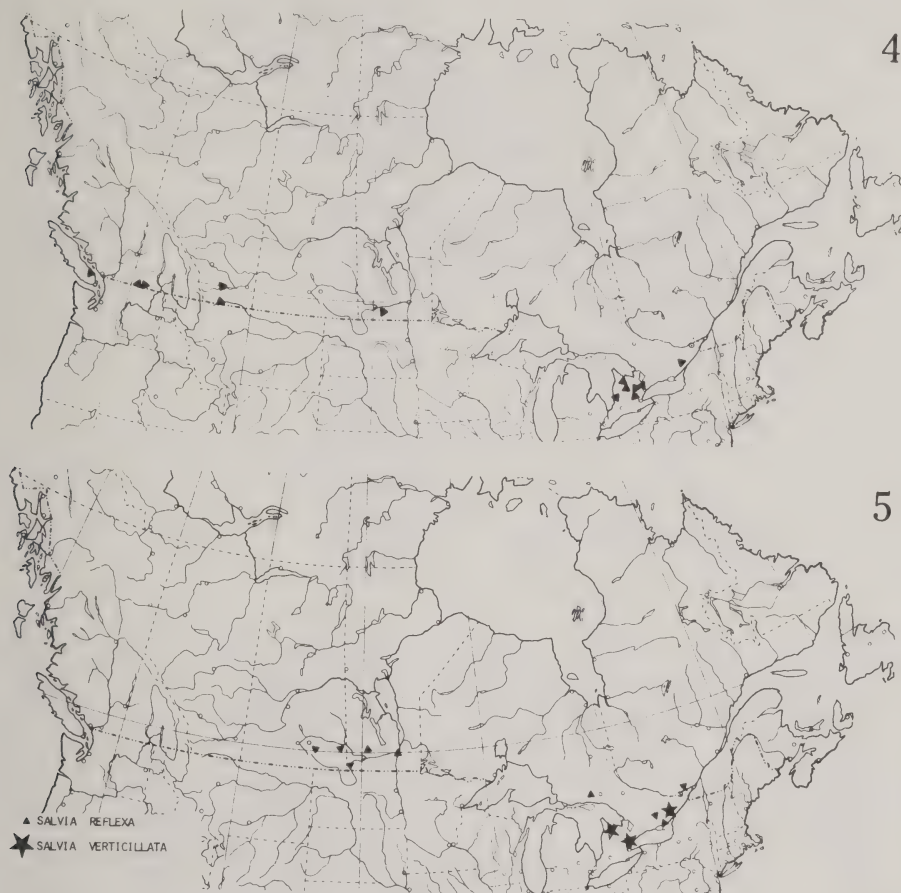


FIG. 4. Canadian distribution of *Salvia nemorosa*. FIG. 5. Canadian distribution of *S. reflexa* and *S. verticillata*.

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(*Claytonia virginica*); photo by Jeffrey Holcombe

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Articles dealing with any phase of botany relating to the Upper Great Lakes Region may be sent to the editor in chief. In preparing manuscripts, authors are requested to follow our style and the suggestions in "Information for Authors" (Vol. 15, p. 238).

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THE GENUS *SPIRANTHES* IN MICHIGAN

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Recent taxonomic work on North American *Spiranthes* (Ladies'-tresses orchids) by Catling, Luer, and Sheviak has resulted in many changes. In 1973, Sheviak recognized *S. magnicamporum*, a prairie taxon, as distinct from *S. cernua* (L.) L.C.M. Rich. in structure, ecology, phenology, and distribution. *Spiranthes ochroleuca* Rydberg has been removed from varietal status under *S. cernua* and restored to species status (Sheviak & Catling, 1980). A puzzling entity, variously treated as a hybrid or as the southern *S. vernalis* Engelm. & Gray was shown to be a valid species, *S. casei* Catling & Cruise (1974; Voss, 1972). Re-examination of herbarium specimens and field exploration by the present authors reveal that all of these newly recognized taxa occur in Michigan. Two southern species, *S. tuberosa* Raf. and *S. ovalis* Lindley, have been recently discovered in the state. *Spiranthes tuberosa* characteristically grows on sandy barrens and old fields south of glaciated regions but extends northward along the east coast. *Spiranthes ovalis* grows in open mature and second-growth woodlands and woodland borders from extreme southern Indiana to Florida and Texas. The presence of both of these species in Michigan represents a considerable range extension northward into glaciated territory.

The changes in taxonomic status and the new range extensions of *Spiranthes* involve Michigan more than any other comparable area of North America. These innovations and discoveries are too recent to have been incorporated into the *Orchids of the Western Great Lakes Region* (Case, 1964) or the first volume of *Michigan Flora* (Voss, 1972). Luer (1975) included only some of the results of the recent taxonomic work, and the range extensions became known after his work appeared. The purpose of this paper is to bring the status of Michigan *Spiranthes* up to date through the presentation of an identification key, photographs taken mostly in Michigan, ecological descriptions referring specifically to Michigan, and maps showing distribution in the state by county.

*Excluded Species**S. vernalis* Engelm. & Gray

Voss (1972) included *S. vernalis* in his *Michigan Flora* on the basis of discussions by Case (1964), determination of a Voss collection by Correll, and the presence of several puzzling collections by various workers. Catling & Cruise (1974) and Catling (1978, 1980) show that most of these formerly difficult specimens represent *S. casei*. A few may represent *S. ochroleuca* or hybrids. *S. vernalis* is not known to occur in Michigan (but see below).

S. ×steigeri

See under *S. romanzoffiana*.

Possible Additions

Considering the previously known ranges of *S. tuberosa* and *S. ovalis* and the relatively large number of coastal plain plants of disjunct occurrence in southwestern Michigan, it seems possible (although unlikely) that *Spiranthes vernalis* and *S. cernua* var. *odorata* may also occur in this region. *Spiranthes vernalis* extends north on the Atlantic coastal plain to eastern Massachusetts and in the interior to southern Ohio. It differs from other northeastern *Spiranthes* in having a rather dense covering of non-glandular pointed hairs in the inflorescence. The flowers of *S. vernalis* (5.0–9.5 mm long) have a white or ivory perianth with the central portion of the lip creamy or pale yellow and are frequently arranged in a rather elongate single spiral. *Spiranthes cernua* var. *odorata* (Nutt.) Correll extends north on the Atlantic coastal plain to southern New Jersey and in the interior to Kentucky. It is distinguished from var. *cernua* by robustness (to 80 cm tall), spreading recurved blades on the cauline sheaths, and relatively large flowers (perianth 10–15 mm long).

Distribution Maps

Catling (1980) examined all of the major and many minor north-eastern herbaria, including AMES, BLH, CM, ILL, MICH, MIN, MO, MSC, NYS, OS, PH, TRT, UMBS, US, and WIS. We based the distribution maps (Fig. 2) which accompany this paper on that work and upon our own recent collections, (deposited in MICH and/or BLH). A listing of the label data providing the basis for the distribution maps is on file at the herbarium of the University of Michigan in Ann Arbor. No well-documented sight records or literature reports were significant enough to be included here.

Key to the Michigan Species of Spiranthes

This key, derived largely from the work of the junior author (Catling, 1980), differs from many previous keys in a greater emphasis upon features of floral morphology at the expense of total reliance on field characters such as flower color, habitat, and geographic distribution.

All measurements of flowers refer to flowers in the lower $\frac{1}{3}$ of the spike. Basal sheaths are those less than 1.5 cm above the roots whereas cauline sheaths are those on the stem 1.5 cm above the roots but below the inflorescence. Fig. 1 illustrates the parts of a typical *Spiranthes* flower.

The key is designed for use with either fresh or dried material. Flower color will be of relatively little value in dried material, but venation of perianth parts will be more readily apparent.

Dried material can be reconstituted in a few minutes by soaking it in 100 cc of warm tap water to which several drops of dishwashing detergent have been added. If pressing has not completely squashed the tissues,

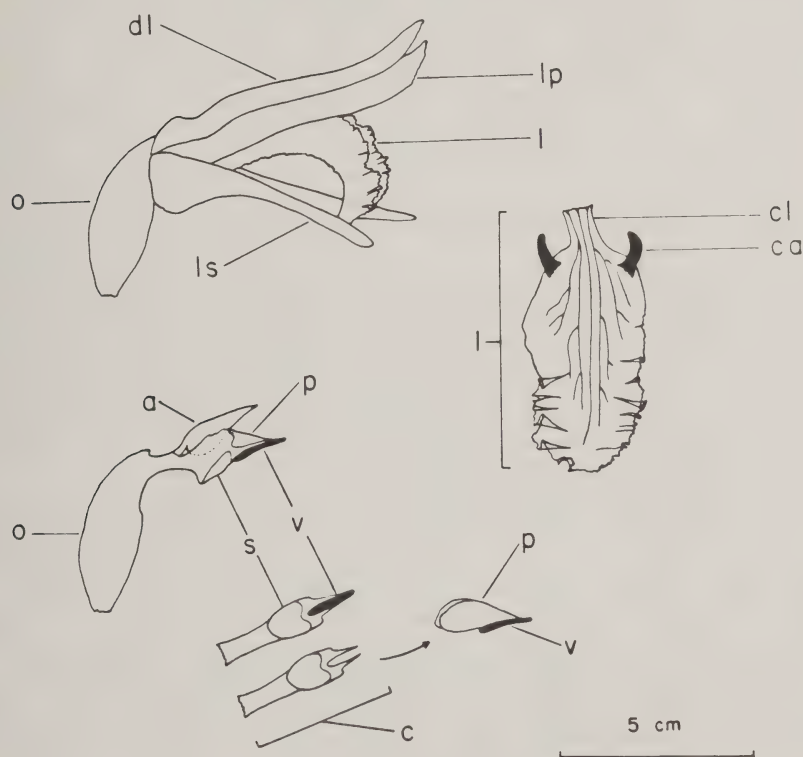


Fig. 1. Diagram illustrating the floral parts of a typical *Spiranthes* flower (*S. vernalis*). a = anther cap, c = column, ca = callus, cl = claw, dl = dorsal sepal, l = lip, lp = lateral petal, ls = lateral sepal, o = ovary, p = pollinia, s = stigmatic surface, v = viscidium.

flowers may even regain their original form so completely that the spreading or appressed nature and position of the perianth parts to one another can be evaluated.

1. Lip pandurate, with lateral venation restricted to the basal two-thirds; sepals basally connate; basal calli usually less than 0.6 mm high; (flowers ivory or creamy white, central portion of lip deep cream or pale yellow).
1. *S. romanzoffiana*
1. Lip not pandurate, with lateral venation extending beyond the basal two-thirds; sepals adnate or not; basal calli various.
2. Viscidium oval, approximately 2–2.5 times as long as wide, sepals basally connate; cauline sheaths 2, rarely 3; (lip bright yellow or orange-yellow even to the tip, somewhat greenish or with greenish veins centrally, perianth otherwise white).
2. *S. lucida*
2. Viscidium linear, more than 3 times as long as wide or absent; sepals always free to the base; cauline sheaths usually (3)4 or more.
3. Lower flowers with perianth, e.g. dorsal sepal, less than 7.5 mm long.
 4. Lower cauline sheaths with or without spreading recurved blades and blades on basal sheaths linear or linear-lanceolate.
 5. Cauline sheaths without spreading recurved blades: (perianth white except for the central portion of the lip which is ivory or pale creamy).
9. *S. cernua* var. *cernua* (depauperate)
 5. Lower cauline sheaths with spreading, recurved blades.
 6. Lateral petals 4.5 (5) mm long or less; inflorescence usually very densely flowered and flowers frequently arranged in 3 vertical ranks; (perianth white except for the central portion of the lip which is often pale creamy).
3. *S. ovalis*
 6. Lateral petals more than 4.5 mm long; inflorescence either densely or loosely spiraled but flowers rarely arranged in 3 vertical ranks; (perianth creamy, yellowish- or greenish-white, lip creamy or yellowish).
8. *S. ochroleuca* (depauperate)
 4. Lower cauline sheaths without spreading recurved blades, and basal sheaths with blades ovate or lanceolate—not linear or linear-lanceolate.
 7. Root single, turbinate, often relatively wide, 5–10 mm wide, ratio of length to width ca. 5; rachis entirely glabrous; perianth relatively short, lateral petals less than 4.5 mm and often exceeded by the lateral sepals by 1 mm; (perianth pure white; lateral veins of the lip diverging at right angles; leaves fugacious; flower gaping from about the middle, the tubular portion less than 3 mm long).
4. *S. tuberosa*
 7. Roots several; rachis conspicuously or minutely pubescent; lateral petals often exceeding 4.5 mm.
 8. Flowers robust, the lateral sepals usually over 2 mm wide; ovary almost as long as the perianth in freshly opened flowers; leaves lanceolate, ± erect, petiole indistinct, length to width ratio 6–20; rachis conspicuously glandular-capitate; (perianth creamy or pale greenish-yellow, the lip deep cream or pale yellow).
5. *S. casei* var. *casei*
 8. Flowers relatively slender, the lateral sepals usually less than 2 mm wide; ovary less than ½ the length of the perianth in freshly opened flowers; leaves ovate, spreading, length to width ratio 1.5–3.5, petiole distinct; rachis only minutely and often sparingly pubescent; (perianth white except for lip which is deep green in the center).
 9. Spike loosely flowered, spike length (mm) / flower number ratio greater than 2.3; basal leaves usually present at flowering time.
6a. *S. lacera* var. *lacera*

9. Spike densely flowered, spike length (mm) / flower number ratio less than 2.3; basal leaves always absent at flowering time.
6b. *S. lacera* var. *gracilis*
3. Lower flowers with perianth, e.g. dorsal sepal, more than 7.5 mm long; (inflorescence \pm densely flowered, usually in a tight spiral, sometimes with flowers in 3 vertical ranks; leaves obovate-lanceolate, linear-lanceolate or linear when present).
10. Basal calli relatively short and conic, as wide as high and usually less than 1 mm high; lateral sepals curved and spreading, often meeting over the top of the flower; leaves absent at flowering time; cauline sheaths with erect sheathing blades often overlapping; (perianth white or ivory, the central fleshy portion of the lip deep cream or yellow; claw very short, less than 0.5 mm long). 7. *S. magnicamporum*
10. Basal calli longer than wide, often 1 mm or more long; lateral sepals \pm appressed; leaves usually present at flowering time; cauline sheaths with blades not ascending or not overlapping.
11. Lip strongly curving from the claw at 25–60°, cuneate at base; claw 0.8–1.5 mm long; (perianth creamy, yellowish- or greenish-white, lip creamy or yellow, perianth mostly 8–9 mm long; basal calli 0.8–1.6 mm, usually more than 1 mm long). 8. *S. ochroleuca*
11. Lip not strongly curving from the claw, the angle less than 30°, cordate or truncate at base; claw 0.3–0.8 mm long; (perianth white except for the central portion of the lip which is ivory or very pale cream, perianth usually 8–11 mm long; basal calli mostly 0.7–1.1 mm long). 9. *S. cernua* var. *cernua*

1. *S. ROMANZOFFIANA* Cham. Hooded Ladies'-tresses, Romanzoff's Ladies'-tresses. Fig. 2, Map 1. 3A

Hooded ladies'-tresses grows in a wide variety of habitats. Rare in southern Michigan, it occurs there almost exclusively in marl fens and alkaline bogs. Northward, it grows on limey shoreline flats and beaches of the Great Lakes, interdunal bogs and swales, roadside ditches, and in non-acid soil regions of cedar-balsam fir swamps. Near Lake Superior, *S. romanzoffiana* sometimes grows in upland fields and roadways in much drier situations. Although widespread and frequently encountered in northern Michigan, Romanzoff's ladies'-tresses rarely forms the large stands so characteristically found with *S. cernua*, even with abundant suitable habitat.

Hooded ladies'-tresses blooms from late July to early September, with most populations at their peak of bloom in early August.

S. \times steigeri Correll, a putative hybrid between *S. romanzoffiana* and *S. cernua* var. *cernua*, has been reported from Barry and Chippewa Cos. (Voss, 1972; Case, 1964). Catling (1980) examined the Barry Co. specimen, and we now consider it to be abnormal *S. romanzoffiana*. No voucher specimen is extant for the Chippewa Co. report.

S. romanzoffiana occasionally hybridizes with *S. lacera* var. *lacera* (Simpson & Catling, 1978; Catling, 1980), but such hybrids have not yet been collected in Michigan.

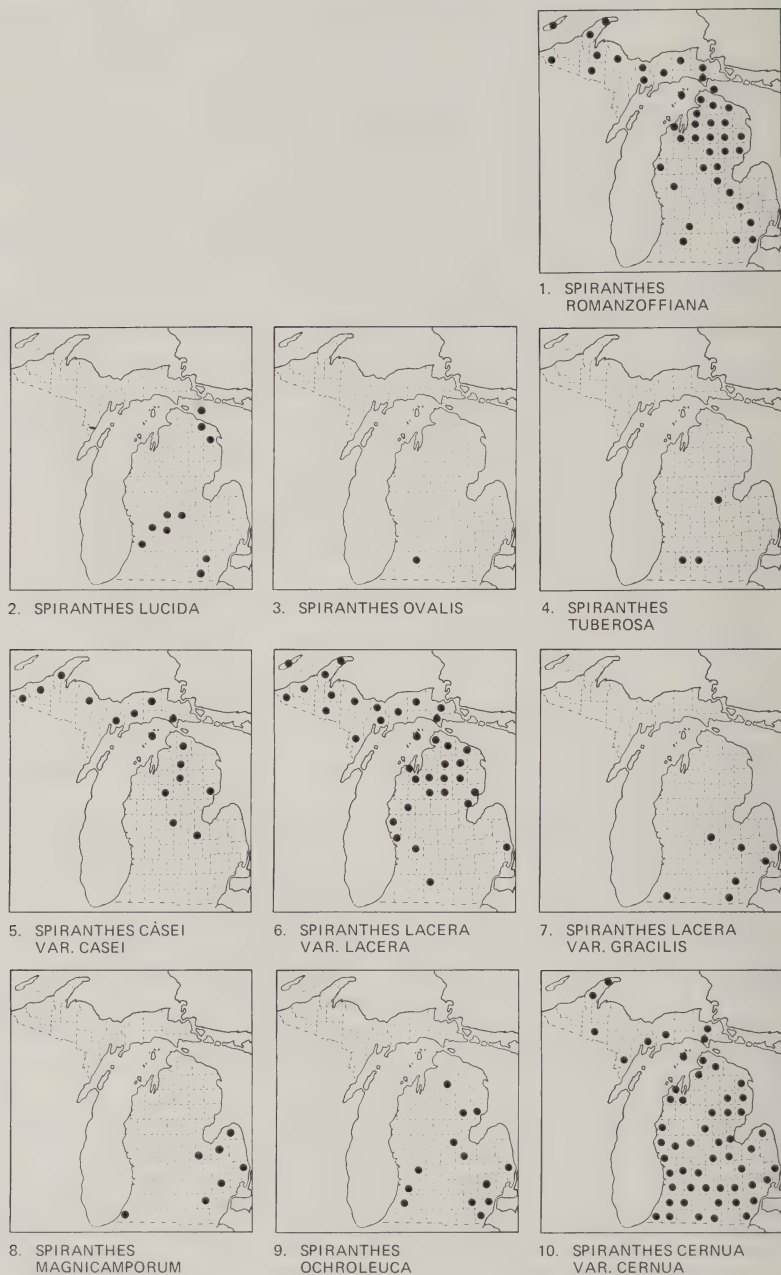


Fig. 2. Distribution of various *Spiranthes* taxa in Michigan.

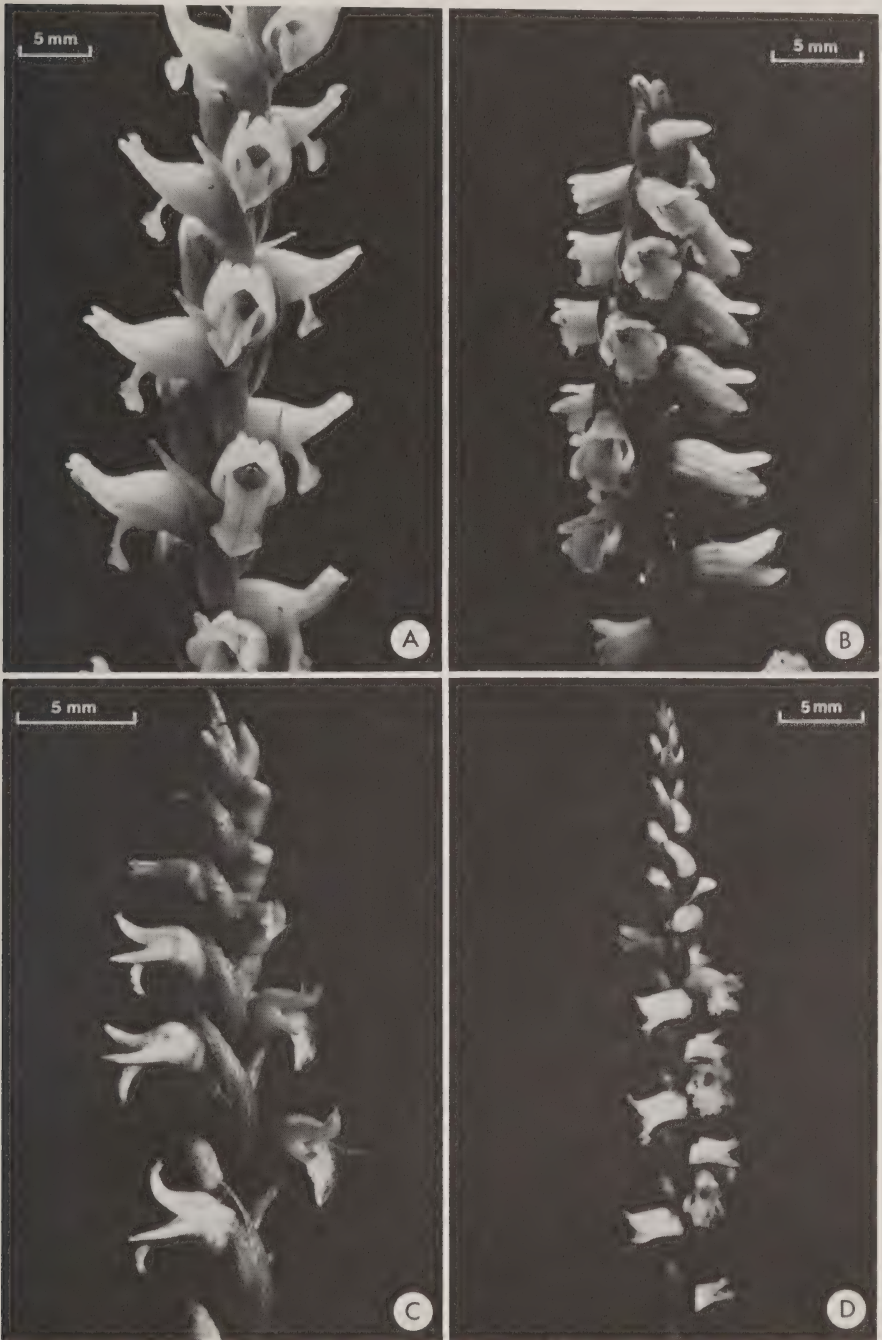


Fig. 3A, *S. romanzoffiana*, Bruce Co., Ont., 27 Aug. 1971, P. M. Catling. 3B, *S. lucida*, Grey Co., Ont., 1 July 1971, P. M. Catling. 3C, *S. ovalis*, Kalamazoo Co., Mich., 26 Sept. 1981, F. W. Case. 3D, *S. tuberosa*, Midland Co., Mich., 8 Aug. 1980, F. W. Case.

2. *S. LUCIDA* (H.H. Eaton) Ames Shining Ladies'-tresses. Fig. 2, Map 2. 3B

With its bright saffron lip and early blooming season, this is our most easily distinguished *Spiranthes*. Shining ladies'-tresses frequents very moist meadows, streambanks, and mossy edges of springs. The plant thrives on disturbance, blooming in heavily pastured wet meadows, along excavated pond margins and in gravel pits, at the high water lap line of small streams and lakes where it is flooded in spring, and more rarely in marl fens. It has been reported from obviously temporary gravel bars in rivers.

Of the dozen or more Michigan colonies discovered or observed over many years, all were on sites disturbed by human activity or recent erosion except one. The largest colony grew on a lakeshore cottage lot where the owner had filled low, marshy ground with bank sand about four years earlier. Several hundred plants thrived briefly in the raw sand.

An unusual feature of this species is the temporary nature of its colonies. The Michigan stands have rarely persisted more than six or seven years in a given location. Its history has been one of appearance, abundance, rapid decline of the colony, and disappearance.

Blooming dates for *S. lucida* vary considerably at any one station from season to season, depending upon the weather, but span the period from early June to early July. The peak of the flowering season in mid-Michigan is about June 18.

A remarkably inconspicuous plant, Shining Ladies'-tresses can be very difficult to detect.

3. *S. OVALIS* Lindley Oval Ladies'-tresses. Fig. 2, Map 3. 3C

Primarily a southern species, *S. ovalis* was first collected in Michigan in 1966 by Dr. R.W. Pippen, in Ross Township, Kalamazoo Co. (WMU). The significance of this discovery was only recently realized, and it is reported here for the first time.

In 1981 the station was visited with Dr. Pippen, who had not been there since his discovery. About 25 plants were found in a moderately mature mixed woodlot dominated by Tulip Tree (*Liriodendron tulipifera*), various oaks (*Quercus* spp.), red maple (*Acer rubrum*), and several exotic trees. Largely a woodland and woodland edge species, *S. ovalis* grew on mossy mounds of soil in moderate shade, and more vigorously in sandy-clayey mowed areas along trails in the woods. Mature plants in deep shade bloomed well. Soil at this habitat was a sandy clay, quite moist, although the habitat was distinctly an upland one.

Until additional stations come to light, this must be considered one of Michigan's rarest orchids. Its presence in an experimental forest with extensive planting of exotic trees raises the question of whether this plant is indigenous or accidentally introduced with forest planting. However, Ohio botanists (pers. comm.) told us that they had recently found *S. ovalis* in a state forest in Lucas Co., Ohio, which is adjacent to Michigan. Sheviak (1974) reports that there has been an apparent increase in the

number of *S. ovalis* populations in Illinois. Here plants primarily occupy disturbed sites and are apparently extending northward. Considering the numerous authenticated records of southern and coastal plain plants which reach their range limits in southwestern Michigan, as well as the nearby Ohio occurrence and recent behavior of the plant in Illinois, it seems reasonable to consider this species as native in Michigan.

Throughout its entire northern range, Oval Ladies'-tresses flowers in late September and early October.

4. *S. TUBEROSA* Raf. Little Ladies'-tresses. Fig. 2, Map 4. 3D

Correll first reported Little ladies'-tresses from Michigan in his *Native Orchids of North America* (1950), basing his report upon collections from Cheboygan Co. (*F.C. Gates 16641*, UMBS, cited in Voss, 1972). Voss (1972) suggested that these specimens were forms of *S. lacera* (Raf.) Raf. (a common species in the northern jackpine barrens), and our examination and measurements confirm this.

In the course of his doctoral research, Catling determined a collection by B. Stergios (528) from Kalamazoo Co. on August 9, 1969, as *S. tuberosa* (MSC). Voss (1957, 1972) cited the specimen under his discussion of *S. lacera*, but since the specimen lacked roots he decided not to admit it to the flora. The presence of a single tuberous root was thought to be the most useful and reliable identification feature, but recent studies have revealed other equally diagnostic characters (see Key).

We visited the Kalamazoo site on August 16, 1980, and found a small colony of about 20 typical *S. tuberosa* plants in an old field habitat.

Earlier in 1980, C. and S. Maisano discovered a colony of 26 unusual *Spiranthes* plants in Midland Co. The plants grew in an abandoned core-sand excavation now being colonized by moss (*Polytrichum*), birch (*Betula papyrifera*), and little else. The plants proved to be typical *S. tuberosa* growing over 100 miles north and east of the Kalamazoo station.

En route to Kalamazoo to examine Stergios' station, we examined an extensive old field in Calhoun Co. Here, we found several well-established colonies of *S. tuberosa* in full bloom. The plants grew in a sandy-gravelly soil (pH 3.9-4.1) with both old-field and prairie plant companions; the dominant grasses included *Leptoloma cognatum*, *Poa compressa*, *Aristida basiramea*, *Danthonia spicata*, and *Andropogon virginicus*. Flowering spurge (*Euphorbia corollata*) and Hawkweed (*Hieracium gronovii*) commonly accompanied the *Spiranthes* here. Plants grew both in hollows and at the crests of low hills, in light shade or full sunlight, frequently in rather open spaces dominated by the moss *Polytrichum*.

S. tuberosa, occurring in three counties, one at some distance from the others, appears well established although rare in southern Michigan. It reaches its flowering peak in mid-August. The basal leaves have withered by flowering time, but new leaves are produced toward the end of the flowering period.

5. *S. CASEI* Catling & Cruise var. *casei* Case's Ladies'-tresses. Fig. 2, Map 5. 4A

S. casei is widespread in the Upper Peninsula, on rocky hills and outcrops of the Keweenaw Peninsula and near Marquette and also occasionally in old fields, borrow pits, and roadside ditches throughout the peninsula. It occurs sporadically in northern Lower Michigan south to Midland and Saginaw Cos. Colonies observed in the sandy areas of central Lower Michigan seem not to persist more than one or two seasons.

The species grows in dry acid soils with *Polytrichum* mosses, poverty-grass (*Danthonia spicata*), bracken fern (*Pteridium aquilinum*), and blueberry (*Vaccinium angustifolium*).

S. casei flowers from mid-August to early September, usually peaking a little earlier than local colonies of *S. cernua*.

- 6a. *S. LACERA* (Raf.) Raf. var. *lacera* Northern Slender Ladies'-tresses. Fig. 2, Map 6. 5A

Northern slender ladies'-tresses usually occurs in dry acid substrates in pine woods or plantations of *Pinus strobus*, *P. resinosa*, *P. banksiana* or on open, sandy or rocky granite barrens and dunes where it occurs with blueberry (*Vaccinium angustifolium*), poverty grass (*Danthonia spicata*), bracken fern, and *Polytrichum* mosses. Rarely, in the Great Lakes region, it has been collected in open bogs, rooted in Sphagnum. It flowers from early July to early August.

- 6b. *S. LACERA* (Raf.) Raf. var. *gracilis* (Bigelow) Luer. See also notes on hybridization under *S. romanzoffiana* Southern Slender Ladies'-tresses. Fig. 2, Map 7. 5B

The var. *gracilis* occurs in rather open dry old fields or prairies in slightly acid or neutral substrates. Common associates are Canada bluegrass (*Poa compressa*), poverty-grass, and wild strawberry (*Fragaria virginiana*). Southern slender ladies'-tresses flowers from mid-August to mid-September. In Michigan, it has been collected in the southern half of the Lower Peninsula.

7. *S. MAGNICAMPORUM* Sheviak Great Plains Ladies'-tresses, Prairie Ladies'-tresses. Fig. 2, Map 8. 4B

This newly recognized species (Sheviak, 1973) was included under *S. cernua* in recent manuals (Case, 1964; Voss, 1972). Luer (1975) did not map it for Michigan.

Although living material of this species is very distinct, some specimens, if poorly preserved, may be difficult for the inexperienced to separate readily from *S. cernua*.

One of the first clear-cut specimens of *S. magnicamporum* from Michigan we collected in Saginaw Co. in September 1980 (Case & Case, MICH). We also found the plant the same year on diked prairie remnants in Tuscola Co. (Case, Case, & Dembinsky, MICH). Dembinsky and



Fig. 4A, *S. casei* var. *casei*, Marquette Co., Mich., 3 Aug. 1978, F. W. Case. 4B, *S. magnicamporum*, Saginaw Co., Mich., 16 Sept. 1980, F. W. Case. 4C, *S. ochroleuca*, Mt. Washington, Berkshire Co., Mass., 10 Sept. 1976, P. M. Catling. 4D, *S. cernua* var. *cernua*, Saginaw Co., Mich., 16 Sept. 1980, F. W. Case.



Fig. 5A, *S. lacera* var. *lacera*, Simcoe Co., Ont., 17 July 1977, P. M. Catling. 5B, *S. lacera* var. *gracilis*, Tuckerton, N.J., 17 Aug. 1976. P. M. Catling.

Riselay sent us specimens of *S. magnicamporum* from Huron Co. growing in two different lakeshore and roadside locations.

Since then, we too have found large colonies of Prairie Ladies'-tresses in Huron Co. Margaret Kohring (pers. comm. 1980), reported seeing the plant in fens in Berrien Co. but did not collect vouchers. On Sept. 7, 1981, Catling collected verifying specimens from an old borrow pit in Berrien Co. (MICH).

We have made a special effort to understand the range of this species in Michigan and have spent a great deal of time observing it in the field. The center of abundance appears to be in moist alkaline sands and prairie soils along Saginaw Bay east of the Saginaw River. Search of accessible habitats west-northwestward of the Saginaw River along Saginaw Bay for 50 miles produced no plants. In Tuscola Co., the plant is occasional but becomes increasingly abundant northeastward as one approaches the subsurface limestone bedrock influence on the soils of the "Thumb." On fallow fields, shoreline cobble, roadsides, and prairie remnants in Huron Co., the plant becomes locally frequent. Elsewhere in Michigan, we have found a very few plants in dry prairie openings adjacent to raised fens in northwestern Oakland Co. (Case, MICH).

Plant companions of *S. magnicamporum* vary considerably but

include *Habenaria leucophaea*, *Cypripedium candidum*, *Spiranthes cernua*, *Liatris spicata*, *Carex* sp., *Juncus* sp., *Potentilla fruticosa*, and *P. anserina*.

In addition to characters mentioned in the key, the gaping yellowish lip and a strong and distinctive, pleasant odor reminiscent of freshly mown alfalfa are useful in identification.

The peak blooming season along Saginaw Bay seems to be earlier than that reported for it from the heart of its range in Illinois and westward (Sheviak, 1973). Our plants bloom in early to mid-September, just as the *S. cernua* bloom begins to decline.

8. *S. OCHROLEUCA* (Rydberg) Rydberg Yellow Ladies'-tresses.
Fig. 2, Map 9. 4C

Yellow ladies'-tresses has at times been included as a variety of *S. cernua*. It is distinct structurally and in habitat (Sheviak & Catling, 1980).

Spiranthes ochroleuca grows in sterile, sandy, open acid woods and fields, often in the company of quaking aspen (*Populus tremuloides*), red maple, bracken fern, wintergreen (*Gaultheria procumbens*), *Viburnum cassinoides*, *Vaccinium* sp., and *Polytrichum* mosses. Colonies are seldom extensive. Blooming commences in early September and reaches its peak in most years in the second and third weeks of that month.

Primarily a species of the Northeast, *S. ochroleuca* is abundant in the southeastern counties, in sandy districts of southwestern lower Michigan, and in counties adjacent to the Saginaw Bay region of Lake Huron. Here, it is widespread on the forested series of concentric beach ridges which formed in Saginaw and Midland Cos. as Saginaw Bay water levels receded following glaciation.

Plants pictured in Case, 1964, and labeled "*S. vernalis*?" are *S. ochroleuca*.

Sheviak & Catling (1980) have discussed triploid hybrids of *S. cernua* var. *cernua* and *S. ochroleuca* which resemble *S. cernua* most closely. These hybrids are most readily recognized in fresh condition. No extensive studies have yet been aimed at determining the status of such hybrids in Michigan.

9. *S. CERNUA* (L.) L.C.M. Rich. var. *cernua* Nodding Ladies'-tresses.
Fig. 2, Map 10. 4D

This widespread species occurs throughout Michigan in old fields, ditches, swales, lakeshores, interdunal marshes, and bogs. It has enjoyed an unusual surge of abundance through the development of colonies of hundreds of plants in the moist sands of borrow pits following the removal of earth for construction of interstate highways.

Nodding ladies'-tresses blooms from mid-August into early October, but blossoming peaks very early in September.

See also notes on hybridization under *S. romanzoffiana* and *S. ochroleuca*.

We wish to thank Richard Phippen for guiding us to his *Spiranthes ovalis* locality and E. G. Voss, Anton Reznicek, and John Freudenstein for help in locating and checking certain critical herbarium specimens. Charles Sheviak gave valued criticism at various stages of this study.

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w THE BREEDING SYSTEM, FECUNDITY, AND DISPERSAL
w OF IRIS LACUSTRIS, ||

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Of Michigan's rare, threatened, and endangered plants, perhaps none is better known than *Iris lacustris*, the Dwarf Lake Iris. This plant has become a symbol of threatened plants in Michigan, probably in large part because it is endemic to the northern shores of Lakes Michigan and Huron. Despite its notoriety, very little is known about its life history or ecology, and for that reason, this study focuses on its breeding system, fecundity, and dispersal.

Crispin (1981) described *Iris lacustris* as a low-growing perennial with slender creeping rhizomes, bearing at the enlarged nodes a fan of flattened leaves less than 6 inches in height. The showy blue flowers are borne singly on short stems and consist of 3 recurved sepals, each with a lighter bearded crest above, which is largely covered by a superimposed petal-like style branch. The petals are shorter than the sepals and alternate with them.—In other words, flowers are typical of iris in miniature (Fig. 1).

Annual growth occurs in the spring by an elongation of the rhizome and production of a terminal sheath of leaves. If flowering is destined to occur, the rhizome forks before elongating, and a flowering shoot is produced in the fork of two terminal sheaths of leaves. This pattern of growth results in a network of ramets which remain interconnected for many years, with the position of past leaf clusters marked by a node swollen with carbohydrates. These swollen nodes mark annual growth increments and can be used to age the plants. In the fall the leaves die back leaving the rhizome to overwinter. The flowers bloom from mid-May until early June, with each flower remaining open approximately three days. The capsules ripen from mid-July until mid-August, releasing brown, oval seeds with a white translucent extension resembling an elaiosome (fat body).

Although abundant where found, the threatened status results from a range limited to the northern extremes of Lakes Michigan and Huron and to a narrow band along the shore. It grows in woods of *Thuja occidentalis* in shaded areas and out from these woods in sunny disturbed areas. Because this is the zone of land around the lakes under the greatest development pressure, further threats are made to an already threatened plant.



Fig. 1. Flower of the Dwarf Lake Iris.

Breeding system

The first step undertaken in studying sexual reproduction in *I. lacustris* was to determine what kinds of pollination (or lack of pollination) is needed to produce fruits. It has been noted (Voss, pers. comm.) that fruit set appears to be quite low. In some plants, fruits can result without the aid of a pollen vector. This can occur either by the plant setting seeds with no pollination at all or by pollinating itself. Both these possibilities seem unlikely in *I. lacustris* because of the showiness of the flower and the indication of low fruit production. The flower structure, in fact, suggests insect pollination. Because *I. lacustris* clones by repeated forking of its rhizome, adjacent flowers frequently belong to the same clone. Insect pollinators would therefore be expected to make numerous pollen transfers among genetically identical flowers. The likelihood of this is increased by the organization of the flower into "multiple pollination units" (Proctor & Yeo, 1972). An insect pollinator is likely to view one *I. lacustris* flower as three, because the 3-part flower presents three

separate paths to possible rewards. Both cloning and 3-part flowers suggest that much pollen transfer likely occurs among genetically identical flowers. The reported low fruit production in *I. lacustris* might therefore be explained by self-incompatibility. Although self-compatibility has been reported for some species of *Iris* (Anderson, 1936), it seemed likely that *I. lacustris* would be different (*i.e.*, self-incompatible).

All of these possibilities were tested by a series of experiments outlined in Table 1. The first two tests (for apomixis and autogamy) determine whether fruit set occurs without the aid of a pollinator. The next two determine if the flowers are self-compatible and how much natural outcrossing occurs among different flowers. The final two experiments are controls.¹ One set of the six experiments was set up at each of 25 locations during May 1982. The locations were distributed as evenly as possible from Wilderness State Park (west of Mackinaw City) around the tip of the Lower Peninsula to Alpena. A geographic spread was deemed desirable to assure that genetic variability in the population was being sampled, *i.e.*, that the 25 observations were independent. "Bagging" was done with styrofoam cups vented near the top with windows covered with mesh; the cups were placed over the flower and pinned into the ground. Tagged flower shoots were wrapped with color-coded telephone wire.

The results are shown in Table 2. In each experiment the sample size dwindled from the original 25 due to vandalism. Although the test for apomixis resulted in one fruit being set, that probably resulted from poor technique during emasculation. Since apomixis is an unusual method of seed production usually resulting in high levels of seed set, it is not sur-

TABLE 1. Breeding experiments.

Apomixis (leads to seed production without pollination). All pollen was excluded from the receptive stigmas of 25 emasculated and bagged flowers.

Autogamy (flowers self-pollinate without the assistance of pollen vectors). 25 flowers were bagged to exclude pollen of all other flowers.

Biologist self-pollinated (leads to a flower setting seeds when pollinated with its own pollen). 25 flowers pollinated with their own pollen as they opened were then bagged to exclude pollen from other flowers.

Natural outcrossing (leads to seeds when pollinated with pollen from a different flower). 25 flowers were emasculated and left exposed. Fruit set would result if pollinators brought in pollen.

Biologist outcrossing (leads to seeds when a biologist applies pollen from a genetically different flower). 25 flowers were pollinated with pollen obtained from plants more than 2 miles distant. The flowers were then bagged to prevent any local and thus potentially genetically identical pollen from being deposited on the stigmas.

Control (no manipulation). 50 flowers were tagged.

¹This research design does not exclude the possibility of pseudogamy, where pollination triggers apomixis even though no fertilization occurs.

TABLE 2. Seed set resulting from breeding experiments.

Experiment	No. of flowers setting seed	% of flowers setting seed	Sample size
Apomixis	1*	5	20
Autogamy	—	—	21
Biologist self-pollinated	17	85	20
Natural outcrossing	3	16	19
Biologist outcrossing	15	71	21
Control	15	39	38

*Perhaps a result of experimental error.

prising that it does not occur in this low fruit-set species. Likewise, it is no surprise that the plants are not autogamous, since the flower arrangement prevents the stamen from touching the stigmatic surface. Also it should be noted that the design of the autogamy test did not rule out apomixis, and therefore lack of autogamy also supports lack of apomixis (except for the remote possibility of pseudogamy). These results suggest that a pollen vector is necessary for fruit set.

Contrary to my expectations the plant is self-compatible. The self-compatibility experiment resulted in 85% fruit set. In fact, of all of the experiments, including the controls, this one resulted in the highest fruit set. The biologist outcrossing resulted in 71% fruit set. Interestingly this rate is significantly lower ($t=8.12$) than the rate the biologist achieved using the flower's own pollen. In other words, selfed flowers set more fruits than outcrossed ones.

Natural outcrossing (with seed set when the pollen vector brings pollen from another flower) resulted in only 16% fruit set. Pollen moved from flower to flower, but only occasionally. The control, where the flowers were not manipulated, resulted in 39% fruit set. The difference between natural outcrossing and no manipulation is statistically significant ($t=13.55$) and suggests that much fruit set results from pollen being redeposited in the same flower.

The first conclusion to be drawn is that a pollen vector is required for fruit set. Literature on other irises suggests that this pollinator may be a bee or a fly (Proctor & Yeo, 1972). Observations by myself and others (Voss, pers. comm.) have failed to disclose the pollinator. Likewise, observations at various times, including night, revealed no flower odor. Atwood (1933) reports that *I. lacustris* is "nearly odorless." However, Small (1924) reports a "violet-scented" odor. Attempts to collect nectar were unsuccessful regardless of time of day. Therefore further work needs to be done to determine the pollinator and its attractants.

The second conclusion is that *I. lacustris* is self-compatible. Without this compatibility, fruit set would be substantially lower. Natural outcrossing experiments resulted in only 16% fruit set. Although the pollen for this outcrossing was definitely from an outside flower, there is no guarantee that the outside flower was genetically different. In fact,

because of cloning, it is probable that a portion of the outside pollen was from a flower of the same clone. Therefore, self- and geitonogamous pollination are significant factors in fruit set.

Fecundity

To get a more statistically meaningful measure of the abundance of flowers and their success in setting fruit, a circular grid 75 cm in diameter (0.44 m^2) was placed near each of the experimental locations. In each of these grids² a count of the growing tips, flowers, and fruits (Table 3) was made shortly after the close of the flowering season so that withered flowers could be counted concurrently with young fruits. Note that flowers and fruits are rather rare when compared to growing tips, fruits in particular being only 3% of the number of growing tips. Perhaps most notable of these results, however, is the variability of the counts. The number of growing tips ranged from 29 to 349, with similar variability in both flowers and fruits. This would seem reasonable if areas with large numbers of growing tips have the largest numbers of flowers and fruits as well. To test this, correlations were calculated (Table 4). The number of flowers did correlate significantly with the number of growing tips, meaning that as the density of growing tips increased, so did the density of flowers. Fruits, however, did not correlate significantly with growing tips or flowers. Thus, fruit set is not a function of flower or growing-tip density. A question then remains as to what factors determine fruit set. Since fruit set requires a pollinator, factors influencing pollinator be-

TABLE 3. Fecundity as indicated by numbers of growing tips, flowers, and fruit (sample area of 0.44 m^2).

	Growing tips	Flowers	Fruits
Range	29-349	2-68	0-26
Mean	176.22	23.23	5.28
(% of growing tips)		13.18	3.00
Standard deviation	83.47	18.22	6.37
N	22	22	22

TABLE 4. Correlations of numbers of growing tips, flowers, and fruits (N = 22).

	Growing tips	Flowers
Growing tips		
Flowers	.81*	
Fruits	.28	.41

*Significant at $\alpha = .05$.

²Three of the 25 experimental plots with excessive poison-ivy were omitted.

havior, such a light intensity, and density of surrounding vegetation, might be worth study.

Fruit set is low, but could be partially compensated for by seed-set per capsule. To get an idea of the potential seed set, flowers were collected just before they opened, and ovules were counted. For completeness pollen was also counted. (Table 5). To estimate actual seed set, (Table 6) capsules were collected from the experiments where the biologist self-pollinated the flowers and where the biologist outcrossed the flowers; two additional unmanipulated capsules were taken from the vicinity (if available) as controls. Seed set averages roughly half the potential as measured by available ovules. It is doubtful that this results from a scarcity of pollen because seed set from the biologist-created crosses are not different from the control even though the biologist applied liberal amounts of pollen. It should be noted that the range of seed set was quite large, and apparently-aborted seeds were often noted.

It is also important to know if the seeds germinate and enter the adult population. A search was made for "seedlings." Very small plants were found in clumps at scattered sites over the range of the plant. From one of these sites I dug up a rectangle 33×90 cm which I took to the laboratory and dissected. The "seedlings" noted in the field (Table 7) proved to be juveniles of various ages and sizes. None of these individuals had ever flowered; but it does appear that seedlings mature and presumably enter the adult population. Yet even when six or seven years old these juveniles are quite a bit smaller than the flowering adults. It thus appears that such plants must be at least seven years old and probably much older before they ever flower.

In conclusion, fruit set is quite low, and fruits are unevenly distributed over the plant's range. A low and extremely variable seed set results in a low but variable level of fecundity.

Dispersal

Mature capsules turn yellow and split from the top along three lines of dehiscence. The small, brown seeds with a white, curled appendage remain attached to the capsule on dehiscence (Fig. 2). On first inspection it was suspected that the seeds might be ant dispersed because the appendage resembles an elaiosome associated with ant-dispersed seeds. Also casual observations never revealed seeds lying on the ground under capsules. Other observations, however, shed doubt on the ant-dispersal hypothesis: (1) open capsules often contained some seeds, and no ants were noted in the vicinity; (2) the capsules do not arch over at maturity and drop out the seeds as in many ant-dispersed species; (3) the seeds have a fairly thin coat which might easily be damaged by ants; (4) a Sudan III test indicated that the "elaiosome" did not contain fats; and (5) juvenile plants found in aggregations near adult plants suggest that the seeds may merely drop from the capsules (*i.e.*, dispersal may be passive). Because of evidence for and against ant dispersal, steps were taken to test the hypothesis of ant dispersal.

TABLE 5. Counts of ovules per capsule and pollen per stamen.

	Ovules	Pollen
Mean	42.43	2,457.6
Standard deviation	4.96	293.1
N	7	9

TABLE 6. Seed set per capsule as a result of biologist pollination and in nature (control).

	Biologist manipulated		Control
	Self-pollinated	Outcrosses	
Mean	22.2	20.7	21.6
Standard deviation	12.5	8.7	8.8
N	11	13	33
Range	4-43	11-40	4-41

TABLE 7. Age distribution and length of longest leaf in juveniles.

Age	N	Mean length (cm)	Standard deviation (cm)
1	33	3.75	.83
2	25	2.77	.66
3	42	3.00	1.00
4	29	3.22	1.30
5	10	3.94	.72
6	6	3.95	1.19
7	1	6.80	—

Preliminary work on dispersal consisted of laying seeds on the ground in an area containing adult plants at Cheboygan State Park. Ants were soon observed carrying off the seeds,³ but in the tall vegetation they were impossible to follow. Therefore, 20 seeds were deposited on the beach in an area clear of vegetation. Within a very short period of time an ant had located the seeds, and within ten minutes several ants had removed all of the seeds. The ants (*Myrmica* sp.) were observed carrying the seeds into their nest, at a distance of about 0.5 m. Suspecting that I had made it easy for the ants by removing seeds from the capsule, I placed a capsule upright in the sand (as they remain in nature) to see if ants would go into the capsule to obtain seeds. Indeed they crawled in and dislodged the seeds, but with some effort. After approximately half an hour, all the seeds were removed and on the way to the nest. The following day on returning to the nest, I found discarded *I. lacustris* seeds outside the ant hole with the "elaiosome" and a portion of the seed coat removed.

³In one instance a centipede was seen carrying off a seed.

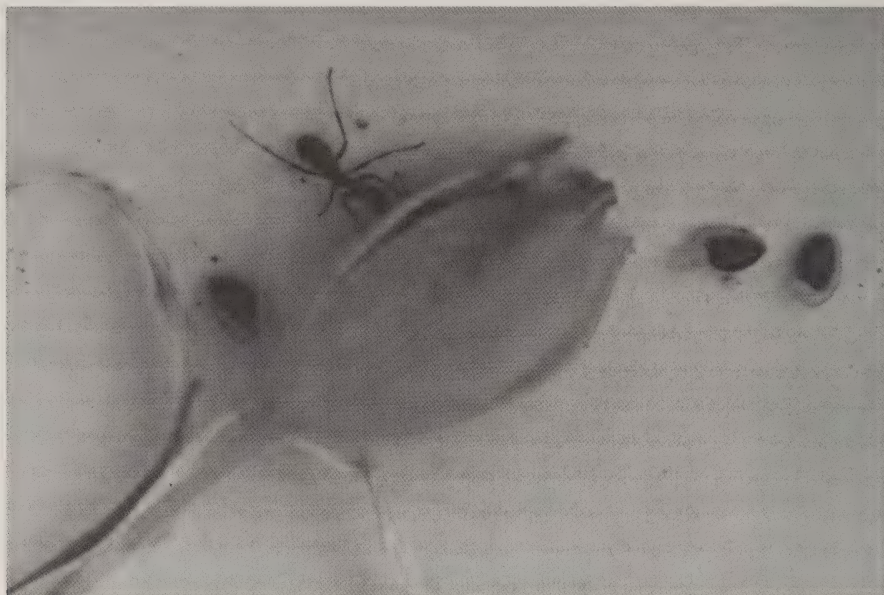
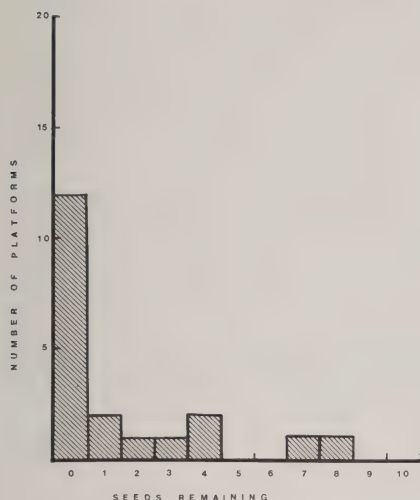


Fig. 2. Ant removing seed from a capsule. Note the white, translucent elaiosome-like structure attached to the seeds.

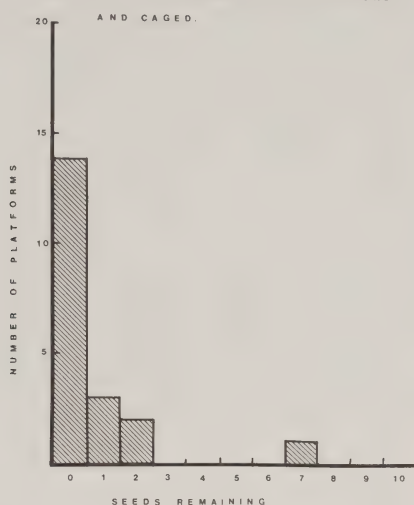
To test quantitatively for ant dispersal, a 4-part experiment (patterned after Heithaus, 1981) was developed. Platforms constructed of wood paneling four inches square mounted on one-inch square posts were placed flat on the ground so that ants could have access to the seeds or raised off the ground and the posts covered with Tanglefoot⁴ to prohibit ants' access to the seeds. To control for rodents, wire cages made of half-inch screen were placed over half the platforms on the ground and half the raised ones. Thus, the four parts of the experiment were (1) an uncaged platform on the ground allowing access to all organisms, (2) a caged platform on the ground allowing access to small crawling organisms, presumably ants, (3) a raised uncaged platform allowing access to rodents, birds, etc., and (4) a caged raised platform allowing access to neither ants, birds, nor rodents. Ten sets of these were located in a woods containing *I. lacustris* near Wilderness State Park. The platforms were placed at one-meter intervals. Seeds from 24 capsules were collected for the experiment; the seeds were mixed in a plastic bag, and sets of ten were placed on each platform. After 24 hours, counts were made of the seeds remaining on each platform. This experiment was repeated two days in a row. A Chi-square Goodness of Fit test indicated that the results from the two days were not significantly different, and so both sets of data were combined.

⁴A sticky substance used to trap insects or to prevent insects from crossing.

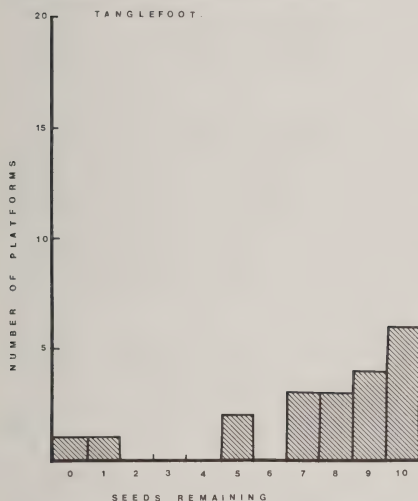
GRAPH 1. PLATFORMS ON THE GROUND.



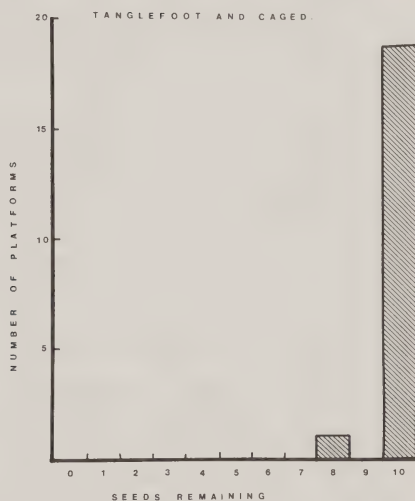
GRAPH 2. PLATFORMS ON THE GROUND AND CAGED.



GRAPH 3. PLATFORMS RAISED, WITH TANGLEFOOT.



GRAPH 4. PLATFORMS RAISED, WITH TANGLEFOOT AND CAGED.



The results are shown in Graphs 1-4. When ants had access to the platforms, they most frequently removed all the seeds, but occasionally they left seeds (Graph 1 & 2). The ant-accessible platforms with seeds remaining at the end of the first day's trial also tended to be the same platforms with seeds remaining on the second day. This suggests that ants may not search far from their nest for seeds, yet Sernander (1906) reports that he observed long-distance ant dispersal from 12 to 70 meters. When ants had no access to the seeds and the seeds were caged (Graph 4), nearly all the seeds remained. However, when ants had no access to the

seeds but the plants were not caged (Graph 3), thus allowing rodents, birds, or any other large creature access, as well as allowing a greater impact of wind, etc., the number of seeds remaining dropped. On returning to this experiment the second time, it was noticed that two seeds remaining on an uncaged ground platform were not iris seeds. These were later identified (by Norton Miller) to be seeds of *Polygala paucifolia*, which are also ant dispersed. The tails of the elaiosomes on these seeds had already been removed. This raises interesting questions about competition of seeds for ants. Not all ants collected at this site have been identified. However, individuals of *Tapinoma sessile* (identified as a seed disperser by Beattie & Lyons, 1975) were attracted to the seeds but seemed too small to carry them off.

The conclusion is that *I. lacustris* seeds are ant dispersed. More than one species of ant is involved in dispersal, and at least one of them seems to be an ant previously associated with seed dispersal.

SUMMARY

The breeding system, fecundity and dispersal were studied. Breeding occurs through self-pollination, geitonogamy, and outcrossing. Flower production is sparse compared with numbers of growing tips; and seed production is even more rare, averaging only 3% of growing tips. On the average there are 21 seeds per capsules or only half of the average number of ovules. The seeds are ant dispersed.

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CHANGES IN TREE COMPOSITION IN A NORTHERN MICHIGAN HARDWOOD FOREST SINCE 1934. ||

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Changes in density, basal area, and composition of tree species with stems greater than 3.8 cm dbh were studied in two small hardwood plots in Cheboygan Co., Michigan. One plot had been selectively thinned at 5-year intervals from 1934 to 1954; the other was unthinned. Importance values were calculated by species for each sample. Sugar maple and basswood were the first and second leading dominants, respectively, for all study years in the thinned plot. Thinning seems to have favored basswood, while beech showed the most negative response. On the unthinned plot sugar maple was the first leading dominant, and beech was second most important. Diversity decreased on both plots, apparently due to loss of species of poor competitive abilities on the unthinned plot and increased dominance of sugar maple on both plots. The number of species increased from 9 to 11 on the thinned plot and decreased from 10 to 7 on the unthinned plot.

Most second-growth hardwood forests in the northern lower peninsula of Michigan resulted from natural reforestation following disturbances. Large-scale lumbering and slash burning were the initial causes of the removal of the original forests and opening of the land. These disturbances were followed by homesteading and pasturing. Early studies of the maple-beech association in the region (Gleason, 1924; Woollett & Sigler, 1928) showed that the remaining virgin stands were characterized, in approximate order of importance, by sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), American elm (*Ulmus americana*), yellow birch (*Betula lutea*), hemlock (*Tsuga canadensis*), basswood (*Tilia americana*), eastern hop-hornbeam (*Ostrya virginiana*), and white ash (*Fraxinus americana*). Reforesting stands were characterized by all of the above in varying proportions with the addition of white birch (*Betula papyrifera*), red maple (*Acer rubrum*), and red oak (*Quercus rubra*).

This study examines changes in composition and abundance in two small plots. The results provide insight into the patterns of succession in the maple-beech association since the early studies by Gleason (1924) and Woollett & Sigler (1928) and serve as a useful reference for more extensive regional vegetational studies. It is recognized that it is impossible to generalize regional vegetational patterns on the basis of two plots; however, long-term documentation on the plots, over nearly half a century, makes the data valuable.

The plots are located on Grapevine Point, a small peninsula extending into Douglas Lake near the University of Michigan Biological Station ((T37N, R3W, sect. 28), Cheboygan Co., 45°35' N., 84°41' W.). White pine (*Pinus strobus*) was cut from the land surrounding Douglas Lake between 1875 and 1880. In addition to cutting choicest pines for lumber,

the early loggers also cut hemlock and stripped its bark for extraction of tannin. Settlement increased after 1880, and by 1895 many of the hardwoods in the immediate vicinity of the lake had been cut. Hardwood logging continued until 1920, with most of the remaining (and less accessible) trees cut between 1911 and 1915 (Woollett & Sigler, 1928). Local fires were common during the logging era and usually occurred repeatedly each year (Gates, 1926). Vast sweeping fires burned the lumbered flats every few years; one recorded in 1895 (probably immediately following logging of that year) blackened all the Biological Station property. Fires mostly ended by the late 1920's as fire protection came to prominence.

The study plots were established in 1934 by Willett F. Ramsdell of the University of Michigan School of Natural Resources (Spurr, 1956) to study long-term effects of selective thinning on hardwood stand improvement. The plots are oriented east-west and are separated by an unmanipulated area approximately 20 m wide; both gradually slope down to the north, along the flank of a low ridge, with drainage occurring directly into Douglas Lake through the Grapevine Point beach area. The soil of the plots is Emmet loamy sand (Foster & Shearin, 1939). One plot 0.4 ha in area (208 ft. by 208 ft.) was selectively thinned at 5-year intervals from 1934 to 1954 (Fig. 1). The other plot (0.2 ha, 208 ft. by 104 ft.), not thinned, served as a control. Trees were cut to improve the residual stand; large, limby, defective trees, undesirable lumber species, and small trees either defective or in coppice clumps were removed. All trees in both plots were measured at 5-year intervals from 1934 to 1954, the 1954 measurement completed by Stephen H. Spurr and student assistants. In 1981 and 1982 the trees were measured again by the author and/or assistants.

In 1934 all trees greater than 3.8 cm (1.5 in.) diameter at breast height were tagged and given identification numbers in both plots (after thinning in the thinned plot). At 5-year intervals from 1934 to 1954 each tree was counted and its dbh measured. As trees reached or passed 3.8 cm in each successive five-year interval, they were also tagged and measured. Plot boundaries marked by permanent corner posts in 1934 were located in 1981. All trees were measured and tagged in like manner by Lynn G. Fisher in July 1981 for the unthinned plot and by the author and assistants in May 1982 for the thinned plot. Diameters were measured with forester's calipers from 1934 to 1949; in 1954 and 1981-82 they were measured with a dbh tape.

Density (trees/ha) and basal area (m^2/ha) were calculated for each tree species for all years of measurement. Species Importance values (Curtis & McIntosh, 1951) were calculated, based on the sum of relative density and dominance divided by two. Importance values for all species in a plot sums to 100. Diversity was measured by species richness (number of species per unit area) and Simpson's Diversity Index (Simpson, 1949) for each plot for 1934, 1954, and 1981-82. Simpson's Diversity Index was scaled so that the maximum value is +1.0 (Whittaker, 1975).

Thinned Plot Results. Before measurement in 1934, 796 trees/ha were removed by selective thinning. The initial cut was comprised mostly of sugar maple, white birch, and basswood. Trees removed from 1939 to 1954 totaled 357 and included sugar maple (169), eastern hop-hornbeam



Fig. 1. Replicate views of thinned plot from corner post #3; *above*—August 1934 after initial thinning; *below*—early June 1982.



(89), basswood (41), beech (25), white birch (24), striped maple (*Acer pensylvanicum*; 7), and red oak (2).

Despite early and extensive losses due to thinning, sugar maple was the leading dominant from 1934 to 1954 and also in 1982 and increased in importance during this period (Table 1). By 1982 sugar maple density had surpassed the post-cut 1934 figure, while its basal area nearly doubled.

Basswood was the second leading dominant for all study years, although its basal area and density were considerably lower than those of sugar maple. Basswood density continually decreased from 1934 to 1982 while its basal area increased, attaining 5.1 m²/ha by 1982. Thinning initially favored basswood, apparently by providing canopy openings that allowed rapid vertical growth. Basswood is expected to become eventually more restricted in the canopy owing to competition from sugar maple. (A decrease in the importance of basswood from 1954 to 1982 supports this view.) White birch showed a pattern similar to that of basswood, but with smaller increases in basal area. Eastern hop-hornbeam density and basal area were low at the termination of thinning in 1954 but by 1982 had increased to the 1934 level. Of the dominant mesic species, beech showed the most negative response to thinning and slowest regeneration, having increased by only 46.9 trees and 0.4 m²/ha basal area in the 28 years after termination of thinning.

The exclusive dominance of sugar maple and much reduced dominance of all other species are similar to the composition of the reforestation areas studied by Woollett & Sigler (1928). The most notable differences are the elevated importance of basswood and eastern hop-hornbeam in this study, indicating that those species may be favored by selective thinning.

Unthinned Plot Results. Sugar maple was the leading dominant for all study years (Table 2). By 1981 sugar maple density had decreased to less than half of the 1934 density, while basal area increased from 8.1 m²/ha to 13.2 m²/ha between 1934 and 1981. Beech was second leading dominant for all study years, comprising a greater proportion of the composition comparatively than basswood in the thinned plot. Beech density decreased at a rate similar to that of sugar maple from 1934 to 1981, but its basal area remained relatively unchanged. Eastern hop-hornbeam had a high stem density in 1934 and 1954 (434.9 and 350.9 trees, respectively), but by 1981 it was reduced to only 59.3 trees. White birch and basswood both showed continual decreases in density over time, corresponding with minor increases in basal area.

The exertion of dominance by sugar maple from 1934 to 1954 appears to be at the expense of other species and especially beech, if competitive displacement is the causal factor for the beech decline. The major reduction of beech basal area occurred from 1944 to 1949, dropping from 8 m²/ha to 5.8 m²/ha. The beech decline levels off after 1954. Sugar maple during the same interval increased in basal area, from 8.2 m²/ha to 9.3 m²/ha. The continued and increased dominance of sugar maple from 1954 to

TABLE 1. Density, Dominance, and Importance Value of species in thinned plot in 1934, 1954, and 1982. Tree data for 1934 and 1954 are computed following selective thinning of those years.

	1934		1954		1982	
	Density	Dominance	IV/2	Density	Dominance	IV/2
<i>Acer saccharum</i>	906.9	8.3	58.0	736.4	8.5	63.4
<i>Tilia americana</i>	202.6	1.6	11.9	163.1	2.8	17.4
<i>Ostrya virginiana</i>	190.3	1.0	9.5	71.7	0.3	4.2
<i>Betula papyrifera</i>	180.4	1.2	9.8	86.5	1.4	8.8
<i>Fagus grandifolia</i>	54.4	1.8	7.9	19.8	0.4	2.4
<i>Fraxinus americana</i>	27.2	0.1	1.4	27.2	0.3	2.2
<i>Quercus rubra</i>	4.9	0.04	0.3	2.5	0.1	0.5
<i>Acer pensylvanicum</i>	22.2	0.04	0.9	9.9	0.05	0.6
<i>Isuga canadensis</i>						
<i>Acer rubrum</i>						
<i>Amelanchier</i> sp.	4.9	0.05	0.3	4.9	0.1	0.6
<i>Ulmus</i> sp.						
Totals	1593.8	14.1		1122.0	13.9	
					1462.8	25.6

TABLE 2. Density, Dominance, and Importance Value of species in unthinned plot in 1934, 1954, and 1981.

	1934		1954		1981	
	Density	Dominance	IV/2	Density	Dominance	IV/2
<i>Acer saccharum</i>	1517.2	8.1	51.8	1329.4	10.4	56.3
<i>Fagus grandifolia</i>	247.1	7.2	24.3	153.2	6.4	17.7
<i>Betula papyrifera</i>	123.6	0.9	4.9	74.1	2.0	6.3
<i>Tilia americana</i>	103.8	0.5	3.3	49.4	1.2	4.0
<i>Ostrya virginiana</i>	434.9	1.1	11.6	350.9	1.7	12.4
<i>Populus grandidentata</i>	4.9	0.2	0.5	2.9	0.6	1.5
<i>Quercus rubra</i>	14.8	0.08	0.5	9.9	0.3	0.8
<i>Ulmus</i> sp.	19.8	0.2	0.9	9.9	0.3	0.8
<i>Acer pensylvanicum</i>	49.4	0.2	1.4	2.9	0.05	0.2
<i>Prunus pennsylvanica</i>	19.8	0.1	0.7			
Totals	2535.3	18.6		1982.6	23.0	
					938.9	29.4

1981 is associated with a decline of eastern hop-hornbeam. Whether these shifts represent progressive and irreversible change (barring major disturbance) or mere fluctuations or dynamic variations measured within the relatively short time of this study is difficult to determine. Certain compositional oscillations are normal within stable communities; future measurements in this plot would afford some sort of answer. One possible preliminary indication of mere fluctuation is the minor increase of beech basal area again after 1954.

The importance of beech as second leading dominant is similar to the condition in virgin or typical beech-maple forests studied by Gleason (1924) and Woollett & Sigler (1928). Gleason (1924) noted that "along a bluff west of Douglas Lake, now cleared, beech originally composed 28 percent of the forest cover." Most notable differences in the present day composition of dominants is the elevated importance of white birch and basswood and the absence of American elm, yellow birch, and hemlock from the canopy.

Diversity Relations, Thinned and Unthinned Plots. Diversity index results varied with method for the thinned plot. Species richness remained at 9 species from 1934 to 1954 and increased to 11 by 1982. Changes from 1954 to 1982 included the loss of elm and the gain of hemlock, red maple, and serviceberry (*Amelanchier*). Values derived by Simpson's index (1949) decreased from .63 in 1934 to .54 in 1954 and .52 in 1982.

In the unthinned plot species richness decreased from 10 species in 1934 to 9 and 7 in 1954 and 1981, respectively. Pin cherry (*Prunus pensylvanica*) disappeared between 1934 and 1954, and elm and striped maple disappeared between 1954 and 1981. Simpson's index values decreased from .60 in 1934 to .51 in 1954 and .43 in 1981.

Diversity (as measured by species richness or Simpson's index) suggests that thinning may have enhanced diversity by permitting species of low competitive abilities to persist or, as in the case of red maple and serviceberry, to invade. Decreases in diversity of both plots (Simpson's index) most likely resulted from the loss of species of poor competitive abilities in the unthinned plot and the exertion of dominance by sugar maple in both plots (Auclair & Goff, 1971). In the unthinned plot the disappearance of pin cherry and striped maple by 1981 can probably be attributed to competition from such species as sugar maple and beech, and perhaps other species. In time white birch and large-toothed aspen (*Populus grandidentata*), both poor competitors (Curtis, 1971), may also be eliminated through competition. These species became established in the plots under an open canopy at the time of the last major logging disturbance (about 1915). The early disappearance of elm (probably American elm) may be related to any of a number of factors, most likely to Dutch elm disease.

The additions of red maple and serviceberry to the thinned plot by 1982 are single trees of each species, and not much can be predicted concerning them. Hemlock can achieve dominance or co-dominance in

certain northern coniferous-hardwood mesic forests, but in a stand which remains undisturbed it will gradually lose out to the hardwoods, particularly sugar maple (Brown & Curtis, 1952). All the hemlocks observed in the thinned plot in 1982 grew on decayed logs or windthrow mounds, and it is unlikely that hemlock will substantially increase in importance in the future. According to the data of the early regional studies all of the species mentioned immediately above (except serviceberry), with the additions of white ash and possibly red oak, are capable of continued maintenance at low levels of importance in the mature maple-beech association. Yellow birch was the only dominant reported in the early studies of undisturbed forests of the region that was not represented in this study.

I am indebted to all persons involved with the establishment of plots and collection of data from 1934 to 1954. Lynn G. Fisher (University of Michigan) graciously gave me the 1981 data for the unthinned plot. Robert Vande Kopple (University of Michigan Biological Station) provided invaluable field assistance in both 1981 and 1982 and Lawrence G. Brewer (Western Michigan University) did likewise in 1982. James Boyle (University of Michigan) suggested the project and gave access to previous data. Roger C. Anderson (Illinois State University), through encouragement and critical review of the manuscript, enabled this study to be completed. I am grateful for the opportunity to work at the University of Michigan Biological Station.

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MICHIGAN FLORA

MICHIGAN FLORA, Part 2, is nearing completion. It will include the first half of the dicots, approximately 950 species, families Saururaceae through Cornaceae—exactly the same families as in vol. 2 of Gleason's *New Britton & Brown Illustrated Flora*. Examination of specimens in herbaria other than the University of Michigan is under way and should be as thorough as possible since, as before, distribution maps will be based only on specimens examined. The holdings of many herbaria have changed in significance since records for part 1 of the *Flora* were gathered over 12 years ago, and some new herbaria have been established. As no significant sources of available records should be overlooked, persons with institutional or private collections under their care and which contain Michigan specimens that might add important distributional records are encouraged (if not already in contact) to notify Edward G. Voss, Herbarium, North University Bldg., University of Michigan, Ann Arbor, Michigan 48109.

NOTICE OF PUBLICATION

Howard Crum's *Mosses of the Great Lakes Forest* is now available in a considerably altered (third) edition from The University of Michigan Herbarium, North University Building, Ann Arbor, Michigan 48109 at \$15.00 (US) plus \$1.00 postage (\$1.75 foreign).

PUBLICATIONS OF INTEREST

RESTORATION & MANAGEMENT NOTES. The University of Wisconsin-Madison Arboretum. \$8.00 for 3 issues, from the University of Wisconsin Arboretum, 1207 Seminole Highway, Madison, Wisconsin 53711. This is a new journal, Vol. 1, No. 1 dated June 1981, that will be of value to people interested in the restoration and management of natural communities. It focuses on prairie, wetland and forest communities and contains articles concerning management in general, as well as shorter notes containing information about specific management problems.

GOLDENRODS OF ONTARIO. SOLIDAGO AND EUTHAMIA. By John C. Semple and Gordon S. Ringius. University of Waterloo Biology Series No. 26. 1983. 84 pp. \$7.00 (Can.), from Dept. of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1. Treating 29 species, including *Aster ptarmicoides* as *Solidago ptarmicoides*, this publication will provide welcome relief for all who have struggled with goldenrods. It is well illustrated, with original drawings by John Semple and Ontario distribution maps for each species. In addition to descriptions, extensive comments about the occurrence, abundance, ecology, and distribution of the species are given. A key, stressing field characters, and introductory material about natural history, hybridization, morphology, and phytogeography preface the taxonomic section.

THE PLANT PRESS—FIELD BOTANISTS OF ONTARIO NEWSLETTER. \$10.00 (Can.) for 4 issues/ year, from The Plant Press, Box 537, Streetsville Postal Station, Mississauga, Ontario L5M 2C1. A new newsletter, Vol. 1, No. 1 dated March 1983, having as its objective the distribution of information about plants and botanists among Ontario field botanists. News about progress on local floras and other projects, additions to published checklists, natural history observations, herbaria, and publications are funnelled through 5 regional editors covering all the province. Additional sections include news of botanists, specimen and information requests, nomenclature update, conservation news, Ontario plants in press, and "Hot off the Press"—giving brief book reviews. This is a thoroughly readable information source that makes it easy to keep up to date on field botany activities in Ontario.

THE VEGETATION OF THE MANISTEE NATIONAL FOREST, OCEANA AND MASON COUNTIES, MICHIGAN¹

I. Physical, Historical, and Ecological Aspects

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An investigation of our forest resources is mandated by the increasing use of forested land for recreation and commerce. As alternative sources of energy are sought, more demands will be placed on renewable forest resources. The contribution of wood fuels to the nation's energy needs has been forecasted to increase from the present 1.6×10^{15} BTU to 4.1×10^{15} BTU by the year 2000 (Tillman, 1978). Substantial growth in the forest products industries is also predicted. It is imperative that ecological assessments and floristic inventories be made of Michigan's woodlands to provide a base for optimal management.

This is the first of two papers characterizing the vegetation of a part of the Manistee National Forest. This paper deals with physical, historical, and ecological aspects. The second will include a list of the vascular flora.

In 1977 and 1978 a portion of the Manistee National Forest was examined floristically and ecologically to obtain information on forest dynamics within the tension zone of Michigan. This study should aid in understanding forest associations in the tension zone and aid the U.S. Forest Service in preparing a natural resources inventory for planning management activities. Because Oceana and Mason Counties and the Manistee National Forest have been poorly collected, this study is an important contribution to the state flora.

The Manistee National Forest, located in the northern Lower Peninsula of Michigan, covers 538,892 hectares (1,331,585 acres) extending from slightly north of Cadillac in central Wexford Co. southward to southern Muskegon and Newaygo Cos. The southern half of the forest lies in the tension zone. Potzger (1948) described the tension zone as a dividing line for climatological phenomena which affect the distribution of many plant and animal species. The study area, located on the western side of the Forest and approximately midway in its north-south dimension on the Oceana-Mason Co. border (43° 50' N, 86° 10' W), includes 6,475 hectares (16,000 acres) of forested land representing 1.2% of the Manistee National Forest (Fig. 1, 2).

¹This paper is based largely on a M.S. thesis completed at Michigan State University, March 1979.

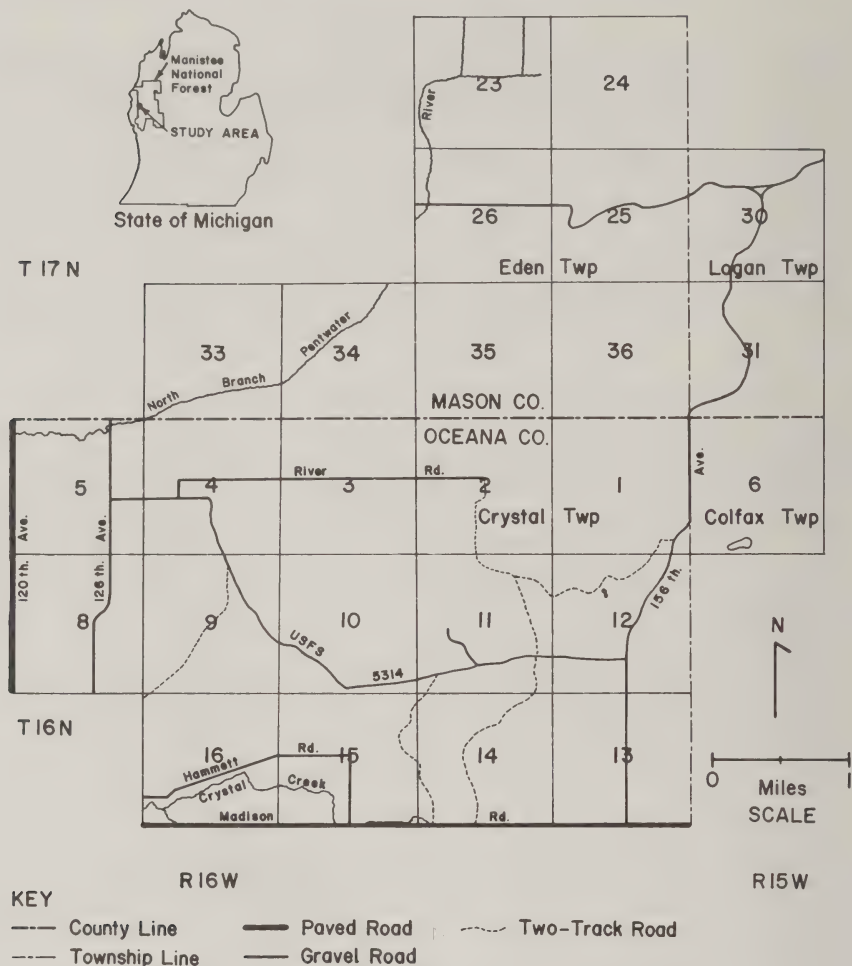


Fig. 1. Map of study area. Inset showing location in the Manistee National Forest.

The climate is influenced by Lake Michigan. Because of prevailing westerly winds, spring and early summer temperatures are cooler than in central and eastern Michigan. Fall and winter temperatures are correspondingly milder. According to the Michigan Dept. of Agriculture (1971), the mean annual temperature is 47°F. The growing season averages 132 days. Precipitation is well distributed throughout the year. The average annual total during 1940–69 was 82.9 cm. Summer precipitation is mainly in the form of afternoon showers and thundershowers. Oceana and Mason Counties lie within Michigan's "Lake Snow Belt" and receive nearly twice the annual snowfall of central and southeastern Michigan. The ameliorating effect of Lake Michigan on the climate has had a strong influence on the vegetation. The moderate winter tempera-

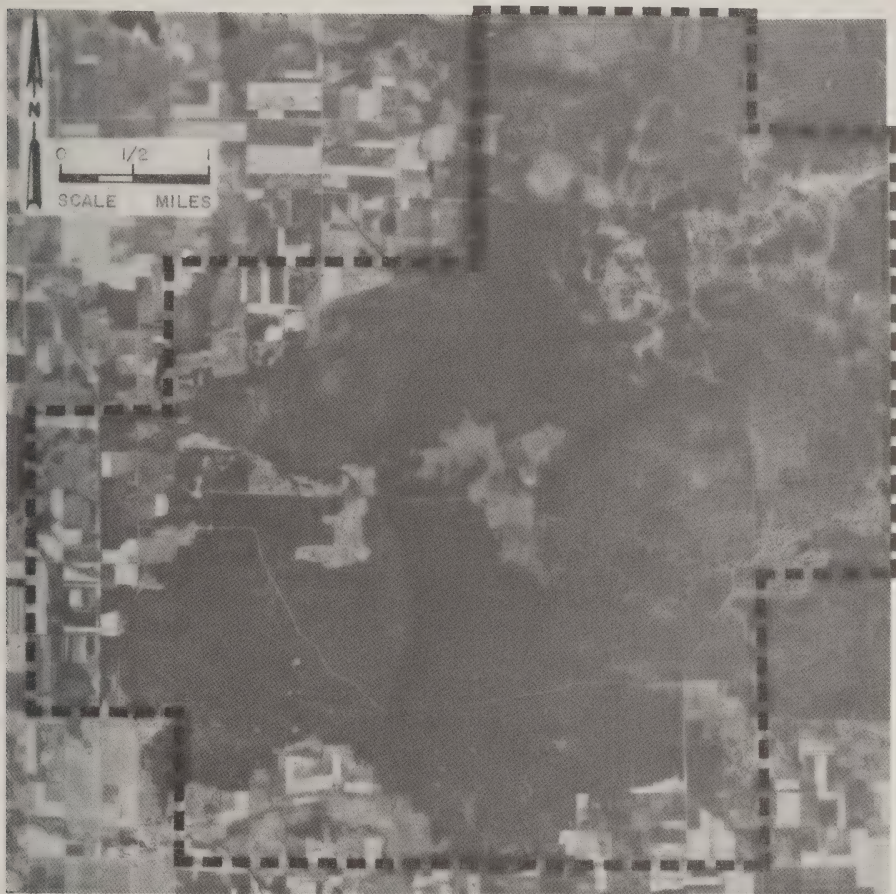


Fig. 2. Aerial photograph of the study area.

tures allow many southern species to extend northward into the area. The abundant moisture and lower evapotranspiration rates enable more mesic species to occur in the well-drained soils of the upland forest.

Most of the area consists of gently rolling morainal deposits. Topographic relief varies from 212 m to 303 m above sea level. Much of the forest is situated on fine glacial sands of the Rousseau series (R1 in Fig. 3). Other soil types include Croswell and Montcalm sands, Deford loamy sand, Mancelona loamy sand, Au Gres fine sand, Roscommon mucky sand, and Carlisle and Tawas mucks.

Oceana and Mason Counties were initially settled for their pine timber (Vandenheuval, 1976), but agriculture subsequently became important, especially near Lake Michigan. By 1894, 46% of Oceana County's acreage had been converted to farmland (Anon., 1895).

Numerous small sawmills were established by the 1870's, and

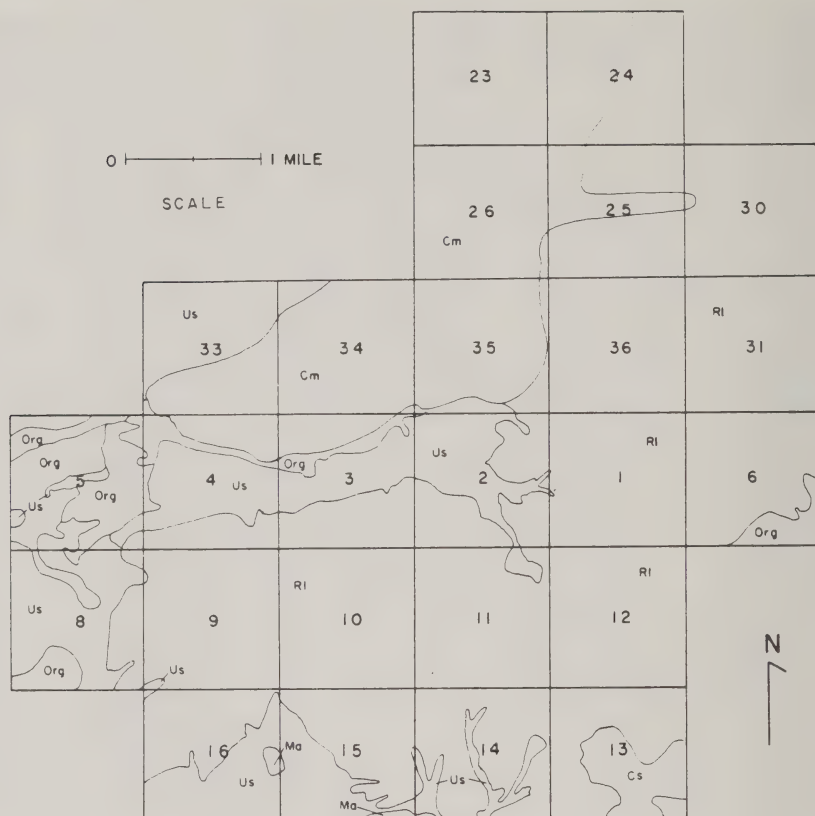


Fig. 3. Soil map of the study area; soil boundaries adapted from Mokma et al. (1972); *Cm*, Carlisle and Tawas Mucks; *Cs*, Coventry fine sand; *Ma*, Roscommon mucky sand; *Org*., organic or poorly drained soils, including Roscommon mucky sand, Deford loamy sand, Wainola loamy fine sand, and Au Gres fine sand. *RI*, Rosseau and Graycalm fine sands; *Us*, heterogenous combination of several minor upland sands, including Croswell and Montcalm sands, Deford loamy sand, and Mancelona loamy sand.

prodigious amounts of white pine and eastern hemlock timber were removed. By the early 1900's much of the forest had been ravaged by the axe. Evidence of the lumbering era remains in the form of numerous stumps and openings where lumbercamps or sawmills once stood. A narrow gauge railroad bed passes through the eastern portion of the study area. A trail where logs were skidded in winter to the North Branch of the Pentwater River can be followed for about 300 m in the upland forest of Crystal Township.

Although no recorded evidence could be found, post-logging fires certainly did occur. This can be inferred from the present forest structure of oaks and aspen, the average ages of the largest trees (ca. 74 years), burned shells of white pine stumps, and multiple tree boles indicating a sprout origin for the majority of oaks.

Human interference remains a significant force against the natural course of forest succession. Numerous oil and gas wells occur near the north and south boundaries of the study area (Fig. 2). Logging is still important, albeit much less than a century ago. The U.S. Forest Service has sold large stands of timber, and many hectares have been clear-cut for pulpwood production.

G. E. McLaughlin of the U.S. Forest Service stated (pers. comm.) that "the only additional planned management activities include harvest and regeneration of mature aspen stands in the northern portion of Crystal Township. Future management activities in adjacent compartments would be dependent upon an inventory of the resources and subsequent preparation through interdisciplinary input of an environmental analysis." It is hoped that this study will aid such an analysis.

During the summers of 1977 and 1978 the upland forest vegetation was analyzed by several methods. Phytosociological sampling of the arborescent vegetation was made by the point-centered quarter technique (Cottam & Curtis, 1956). Six 500-m line transects were established at six locations in Crystal Township, Oceana Co. Data were recorded for 1296 trees 2.54 cm in diameter at breast height or larger.

A modified line intercept technique (adapted from Lindsey, 1955) was used for ground cover studies of canopy trees. Twenty 30 m tape transects were established, and the interception distance traversed by the crown of each canopy member was recorded for 123 trees.

Twenty-five 4×5 m quadrats were used to determine density and frequency values of tree seedlings and saplings. The differentiation of seedling and sapling stages is based on Cottam's classification (1949)—seedlings less than 30 cm tall; saplings more than 30 cm tall but less than 2.54 cm d.b.h. Trees are defined as greater than 2.54 cm d.b.h.

One-hundred 1 m^2 quadrats were used for quantitative studies of the herbaceous stratum. The quadrat and point-centered quarter data were analyzed by computer programs developed by Kathleen A. Kron of Michigan State University to calculate density, dominance, frequency, and importance values (Cox, 1976).

Minor habitats were studied qualitatively. Transects were walked through wetlands, (forested, persistent emergent, and scrub-shrub wetlands), bracken-grasslands, old fields, and oil well openings, and vouchers were collected for every species.

DESCRIPTION OF VEGETATION

Presettlement Forest

Records of the General Land Office Survey of 1838 show white pine (*Pinus strobus*) to be the dominant species of the presettlement forest, with American beech (*Fagus grandifolia*) and eastern hemlock (*Tsuga canadensis*) also important. Relative density (percent occurrence), relative dominance (percent total basal area), and importance values (Hushen et al., 1966), are presented in Table 1. The overwhelming dominance of white pine in the presettlement forest is evident. The importance value for white pine (101.7) is over two and a half times that for American beech (38.4), the second most important species in the presettlement forest. Third in importance was eastern hemlock which did not appear to be common on sandy upland sites but favored more mesic habitats. Today, eastern hemlock is found only in forested wetlands or wet ravines, being completely absent from upland sites. Red oak (*Quercus rubra*), red maple

TABLE 1. Presettlement forest of 1838 on sandy upland soils.

	No. of Individuals	Total Basal Area (dm ²)	Ave. Basal Area	Relative Density	Relative Dominance	Importance Value
<i>Pinus strobus</i>	63	1906.6	30.3	36.0	65.7	101.7
<i>Fagus grandifolia</i>	52	253.3	4.9	29.7	8.7	38.4
<i>Tsuga canadensis</i>	24	165.4	6.9	13.7	5.7	19.4
<i>Quercus rubra</i>	10	274.4	27.4	5.7	9.5	15.2
<i>Acer rubrum</i>	16	135.3	8.5	9.1	4.7	13.8
<i>A. saccharum</i>	10	108.9	10.9	5.7	3.8	9.5
<i>Quercus alba</i>	2	34.3	17.2	1.1	1.2	2.3
<i>Pinus resinosa</i>	1	16.4		0.6	0.6	1.2
<i>Ulmus americana</i>	1	7.3		0.6	0.3	0.9
Total	175	2901.9				

(*Acer rubrum*), and sugar maple (*Acer saccharum*) were of secondary importance in the presettlement forest. Red oak had a higher relative dominance value than beech or hemlock, indicating that large, sexually mature individuals (ave. basal area = 27.4 dm²) were present in the upland forest.

Present Forest

Following the white pine lumbering era and subsequent fires, the relative abundance of the forest components was dramatically changed. Red oak (*Quercus rubra*)¹ is now the dominant species, showing an importance value of 95.2 in the point-centered quarter studies (Table 2). Canopy cover analyses indicate that red oak forms nearly 61% of the ground cover (Table 3). Table 4 shows red oak to have significant representation in all size classes, suggesting a continued ecological importance in the future.

Big tooth aspen (*Populus grandidentata*), second in importance according to the point-centered quarter analysis, ranks third in the size class ordination (Table 4) where species are ranked by relative dominance and fifth in percent crown cover (Table 3). The reason for the differential ranking is inherent in the nature of the analyses and in the fact that big tooth aspen is a smaller tree. It is, therefore, represented by numerous individuals in the smaller size classes, particularly in the second (10–22.6 cm). Its resulting high relative density and frequency values determine its higher placement in the point-centered quarter studies. Likewise its smaller trunk and canopy diameters account for the lower placement in Table 3.

¹The forest is dominated by the "red oak complex" (*Quercus rubra*, *Q. rubra* var. *borealis*, and *Q. velutina*). Due to difficulty in recognition in the field, these three taxa were treated as one. *Quercus velutina*, being near its northern distributional limit (Little, 1971), is very poorly represented in the upland forest, comprising less than 1% of the "red oak" individuals.

TABLE 2. Point-centered quarter data for density, dominance, frequency, and importance values for woody species 2.54 cm or greater d.b.h.

	No. of Individuals	Ave. Dominance (cm ²)	Density (ha ⁻¹)	Relative Density	Relative Dominance	Relative Frequency	Importance Value
<i>Quercus rubra</i>	260	623.96	229.71	20.14	54.38	20.63	95.16
<i>Populus grandidentata</i>	189	145.50	166.98	14.64	9.22	13.42	37.28
<i>Acer rubrum</i>	180	109.08	159.03	13.94	6.58	15.22	35.74
<i>Pinus strobus</i>	206	53.23	182.00	15.96	3.68	11.84	31.47
<i>Quercus alba</i>	103	409.29	91.00	7.98	14.13	9.25	31.35
<i>Fagus grandifolia</i>	120	114.72	106.02	9.30	4.62	9.13	23.04
<i>Sassafras albidum</i>	129	45.79	113.97	9.99	1.98	10.49	22.46
<i>Acer saccharum</i>	73	199.71	64.49	5.66	4.89	6.88	17.42
<i>Prunus serotina</i>	11	85.36	9.72	0.85	0.32	0.90	2.07
<i>Amelanchier</i> spp.	10	11.63	8.84	0.78	0.04	1.13	1.94
<i>Fraxinus americana</i>	4	96.95	3.53	0.31	0.13	0.45	0.89

TABLE 3. Canopy cover values for upland forest trees.

	No. of Individuals	Interception Distance (m)	Mean Line Cover (m)	m ² Cover/ha	% Ground Cover
<i>Quercus rubra</i>	70	363.00	18.15	6,050	60.50
<i>Q. alba</i>	21	86.05	4.30	1,434	14.34
<i>Acer rubrum</i>	12	74.00	3.70	1,233	12.33
<i>Fagus grandifolia</i>	5	39.80	1.99	633	6.63
<i>Populus grandidentata</i>	7	25.30	1.27	422	4.22
<i>Acer saccharum</i>	3	13.60	0.68	227	2.27
<i>Sassafras albidum</i>	2	4.80	0.24	80	0.80
<i>Fraxinus americana</i>	2	4.50	0.23	75	0.75
<i>Prunus serotina</i>	1	4.10	0.21	68	0.68
Total	123	615.15			

TABLE 4. Size classes of upland forest trees. Species arranged in decreasing order of relative dominance.

	No. of Individuals	Size class 1 2.5-9.9 cm		Size class 2 10.0-22.6 cm		Size class 3 22.7-40.4 cm		Size class 4 >40.5 cm		Relative Dominance
		Relative Density	Basal Area (dm ²)	Relative Density	Basal Area (dm ²)	Relative Density	Basal Area (dm ²)	Relative Density	Basal Area (dm ²)	
<i>Quercus rubra</i>	260	5.45	21.52	5.60	154.72	5.99	588.44	3.19	860.96	54.4
<i>Q. alba</i>	103	2.49	9.81	2.57	52.79	2.26	228.16	0.70	130.20	14.1
<i>Populus grandidentata</i>	189	7.24	23.26	6.46	180.83	1.01	68.84			9.1
<i>Acer rubrum</i>	180	10.04	30.04	2.96	62.53	0.93	68.21	0.80	32.95	6.5
<i>A. saccharum</i>	73	3.35	11.91	1.48	32.13	0.62	49.68	0.23	52.05	4.9
<i>Fagus grandifolia</i>	120	5.84	16.14	2.88	64.59	0.54	42.66	0.08	14.30	4.6
<i>Pinus strobus</i>	206	12.84	45.99	3.11	59.19	0.08	4.48			3.7
<i>Sassafras albidum</i>	129	9.03	37.57	0.93	14.69	0.08	6.82			2.0
<i>Prunus serotina</i>	11	0.39	0.95	0.47	8.44					0.3
<i>Amelanchier</i> spp.	10	0.78	8.40							0.3
<i>Fraxinus americana</i>	4	0.23	1.03	0.08	2.85					0.1
Total	1285		206.62		632.76		1057.29		1090.46	

The presence of big tooth aspen is directly correlated with past disturbance. Big tooth aspen was not referred to by the surveyors in 1838, perhaps due to a reluctance to blaze aspens because of their relatively short life spans. Even so, big tooth aspen presumably had little importance in the presettlement pine forest due to shade intolerance. After logging and subsequent fires, conditions considerably favored the establishment of big tooth aspen. The aspen trees present today represent sprouts from post-lumbering era individuals and are approximately 55 years old. Big tooth aspen cannot successfully reproduce in the shade of the forest. The paucity of aspen seedlings and saplings is shown in Table 5. It should be noted that *Populus* is being regenerated throughout the area in large tracts clear-cut for pulpwood.

Red maple, white pine, and white oak are third, fourth, and fifth, respectively, in importance in the point-centered quarter treatment. They are common in all size classes, except that white pine is represented by smaller understory trees and is thus poorly represented in the third size

TABLE 5. Density, frequency, and importance values for tree seedlings, saplings, and shrubs.

	Density	% Frequency	Importance Value
Seedling stratum			
Acer rubrum	.67	88	29.06
Quercus rubra	.54	92	25.85
Viburnum acerifolium	.75	36	24.95
Quercus alba	.49	84	23.57
Sassafras albidum	.40	96	22.43
Prunus spp.	.19	68	13.45
Amelanchier spp.	.11	60	10.29
Fagus grandifolia	.09	52	8.62
Hamamelis virginiana	.06	24	4.42
Acer saccharum	.07	20	4.22
Fraxinus americana	.03	16	2.75
Populus grandidentata	.002	04	0.54
Sapling stratum			
Acer rubrum	.08	44	7.43
Sassafras albidum	.03	32	4.56
Viburnum acerifolium	.04	24	3.93
Amelanchier spp.	.02	16	2.36
Quercus alba	.02	16	2.36
Fagus grandifolia	.01	16	2.25
Quercus rubra	.01	12	1.66
Hamamelis virginiana	.01	8	1.35
Prunus spp.	.01	8	1.13
Acer saccharum	.02	4	1.03
Populus grandidentata	.01	4	0.70
Fraxinus americana	.002	4	0.54
Pinus strobus	.002	4	0.54

TABLE 6. Density, frequency, and importance values for herbs.

	Density	Dominance	% Frequency	Importance Value
<i>Carex pensylvanica</i>	21.96	15.40	63	89.27
<i>Pteridium aquilinum</i>	2.01	13.81	65	39.83
<i>Vaccinium angustifolium</i>	1.48	2.59	21	11.78
<i>Gaultheria procumbens</i>	2.02	0.66	30	11.64
<i>Rubus</i> spp.	0.32	0.66	16	4.92
<i>Desmodium nudiflorum</i>	0.41	0.38	7	2.94
<i>Oryzopsis asperifolia</i>	0.19	0.44	9	2.90
<i>Solidago</i> sp.	0.22	0.24	10	2.84
<i>Danthonia spicata</i>	0.41	0.23	2	1.73
<i>Epifagus virginiana</i>	0.33	0.40	1	1.63
<i>Maianthemum canadense</i>	0.08	0.05	5	1.23
<i>Aralia nudicaulis</i>	0.07	0.25	2	0.96
<i>Comptonia peregrina</i>	0.06	0.13	3	0.93
<i>Epigaea repens</i>	0.07	0.04	3	0.81
<i>Corallorhiza odontorhiza</i>	0.04	0.02	2	0.47

class and absent from the fourth (Table 4). Red maple is common in all strata, being dominant in seedling and sapling layers. The canopy cover data show white oak with its generally wider crown to be the second most important canopy component with 14.3% ground cover, closely followed by red maple (12.3%). White pine was not encountered as a canopy component.

Beech and sugar maple, the principal forest components of southern Michigan woodlots, have rather low importance in all strata. Beech is frequent in the canopy and sub-canopy, while sugar maple is poorly represented.

Sassafras albidum, being a smaller tree, is only occasional in the canopy, usually in disturbed areas with *Populus grandidentata* or in openings in the oak canopy. *Sassafras* is more important in the first size class (2.5 to 9.9 cm). The quadrat data indicate its importance in the seedling and sapling strata (Table 5). The oldest *sassafras* trees, approximately 73 years old, date from the last major fire.

Prunus serotina, *Amelanchier* spp., *Fraxinus americana*, *Hamamelis virginiana*, and *Ostrya virginiana* were encountered to varying degrees in the understory and seedling and sapling strata. None gain prominence over large areas, although *Hamamelis* may be locally important.

Comparative data for the herbaceous stratum of the upland forest are summarized in Table 6. Pennsylvania sedge (*Carex pensylvanica*) is the dominant herbaceous species and is ubiquitous in the forest. *Carex* shows a remarkable range of light tolerance, being found in full sun and deep shade. Bracken fern (*Pteridium aquilinum*), the second most important herb, often forms dense stands in open areas (bracken-grasslands). Nearly pure stands result in clear-cut tracts under the young aspens.

DISCUSSION

The forests of northern Michigan are intermediate in composition between deciduous forests to the south and coniferous forests to the north (Maycock & Curtis, 1960). In northern Michigan, local disturbance, edaphic factors, and microclimatic conditions tend to favor one or another forest type, resulting in a mosaic of "climax" associations. The co-dominant taxa vary proportionally as a result of different but overlapping ecological tolerances (Curtis, 1959).

Parmelee (1953) observed that it is not the species present as much as the relative amount of each which characterizes the climax forest. As both Parmelee (1953) and Harvey (1919) contended, upland oak forests are the stable, mature "climax" forest type on the sites where they are found. The widespread occurrence of a red oak-dominated association in the Manistee National Forest and the data from the study area suggest that on those sites which presently support an oak association, oaks should continue to be dominant. Red oak was also important in the pre-settlement forest of 1838. After release from competition with the pines, red oak was better adapted to the environment than sugar maple or beech and hence assumed dominance. This is not to say that beech and sugar maple are not capable of being climax dominants in this region. Whitford (1901), Elliott (1953), Overlease & Overlease (1976), and others have shown that beech-maple forests are common in northern Michigan; therefore, environmental conditions can support such a forest type. However, because of the soils and history of the study area, a beech-maple dominance is not favored here. The apparently low reproductive ability of the oaks compared to red maple, sugar maple, and beech obviously does not preclude them from successful competition. Parmelee (1953) observed the same phenomenon in southern Michigan oak forests and demonstrated the ability of *Quercus* to maintain dominance indefinitely. Based on these facts, and in light of selective cutting and clear-cutting operations now underway in the study area, a continued red oak-dominated association appears to be favored as the climax forest type.

SUMMARY

The Manistee National Forest study area is an oak-dominated association. The forest, approximately 75 years old, is derived from a white pine-beech-mixed hardwoods presettlement forest. Associated trees are *Populus grandidentata*, *Acer rubrum*, *Pinus strobus*, *Quercus alba*, and *Fagus grandifolia*. The sapling/shrub layer is dominated by *Acer rubrum*, with *Sassafras albidum*, *Viburnum acerifolium*, *Amelanchier* spp., *Quercus alba*, and *Fagus grandifolia* well represented. The seedling/herbaceous layer is characterized by *Carex pensylvanica*, *Pteridium aquilinum*, *Acer rubrum*, and *Quercus rubra*. Given the soils, past history, and microclimatic features of the area studied, a red oak-dominated climax association is proposed as the future forest type.

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REVIEW

A FLORA OF WATERTON LAKES NATIONAL PARK, by Job Kuijt. 1982. University of Alberta Press, Edmonton, Alberta, T6G 2E8. xxiv + 684 pp. \$15.00 CAN paperback, \$25.00 CAN hardcover.

Here is a fine illustrated flora of one of Canada's beautiful national parks. The park, in Alberta, is just north of and contiguous with Glacier National Park, Montana, and this flora will be useful there as well.

Floristically, Waterton Lakes is of considerable importance to Canada. It contains a high proportion of the rare species of Alberta and the only Canadian localities for some Rocky Mountain species such as *Stellaria americana*, *Aquilegia jonesii*, and *Douglasia montana*.

The book has introductory material including short discussions of earlier botanical work, the geography of the flora, the physical setting of the park, and basic vegetation types. A map of the park (however, without all the localities mentioned in the text) is on both the front and back inside covers. A short glossary is provided at the end. A section including statistics on the flora and a more detailed discussion of floristic affinities would have been welcome.

The main text treats all vascular plants and has keys to families, genera, and species. Families, genera within families, and species within genera are all alphabetical. The keys look workable, and the family key is designed to lead the user quickly to such large, distinctive families as the Compositae, Leguminosae, Gramineae, etc. However, this is done through a series of couplets using the uninformative second lead "not the above combination of characters." The key does account later for certain exceptional genera, such as the legume *Petalostemon*, whose flowers do not fit the papilionaceous pattern. For each species are a brief description and then usually notes about habitat, distribution, and abundance in Waterton Lakes Park, further taxonomic refinements, and flowering times. Technical terminology is avoided where possible. All but a few species are illustrated, with eight particularly showy species having color photographs. The illustrations are usually good. The silhouettes of inflorescences in the Gramineae and Cyperaceae lack usable detail; however, detailed enlargements of spikelets, achenes, and perigynia are provided for each species.

The book is well laid out, exceptionally free of typographical errors, and well bound. It will be an excellent companion for botanists, amateur or professional, visiting that area of the Rocky Mountains. At \$25.00 Canadian (\$15.00 for paperback) for a 684 page book, it is also a good value for one's money.

—A. A. Reznicek

PUBLICATIONS OF INTEREST

ALEKSANDER TAMSALU 1891–1960 A BOTANIST IN EXILE. By John B. Lord. Royal Botanical Gardens Tech. Bull. 11. 1980. 126 pp. \$3.50 [+ \$1.00 postage (Canad.)], from the Gardens, Box 399, Hamilton, Ontario, Canada L8N 3H8]. A fascinating and in many ways tragic story of an Estonian political refugee whose path eventually, by way of Connecticut, led him to the Royal Botanical Gardens, Hamilton, Ontario, where he collected extensively (preparing over 9800 herbarium specimens) and made a detailed survey of native plant communities according to the phytosociological system of vegetation analysis employed earlier in his career in Europe. This is a substantial and well illustrated and documented account of a man with incredible energy in the face of adversity—good reading for any botanist!

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On the cover: *Dicentra cucullaria*,
the Dutchman's Breeches,
photographed by Kenneth A. Wagner

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THE

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24/6
HYBRIDIZATION IN *TYPHA* IN
GENESEE COUNTY, MICHIGAN [J] ✓

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Voss (1972) in his *Michigan Flora* refers the Cat-tails of the state to two species, the Narrow-leaved Cat-tail, *Typha angustifolia* L., the Common Cat-tail, *Typha latifolia* L., and the hybrid between these two species, *Typha* × *glauca* Godron. Although his distribution maps show that both of the parent species occur in a few of the adjoining counties, he gives no record for *Typha* from Genesee County. However, based on our observations the genus is of widespread occurrence in the county, and therefore a study was undertaken to provide percentage figures based on a random sampling for *Typha latifolia* (a well-known frequenter of clean marsh habitats), *T. angustifolia* (a species better equipped for dealing with pollutants and a eutrophic environment), and *T. × glauca*.

The hybrid nature of *T. × glauca* has been confirmed by Smith (1967) and further verified by electrophoresis (Lee & Fairbrothers 1973). Because these three taxa may exhibit quantitative overlap in their standard field characteristics, e.g. leaf width or spike interval, we also scored the less environmentally modifiable microscopic floral characteristics (Hotchkiss & Dozier 1949; Fasset & Calhoun 1952; Smith 1967; Bayley & O'Neill 1971) in order to make positive identifications of randomly selected specimens.

Forty specimens from 15 sites were selected at random and analyzed in the field for 1. leaf width (using the third cauline leaf from the apex of the flowering spike, measured just above the sheath-blade transition region); 2. spike interval (measured from the top of the pistillate portion of the flowering spike to the base of the staminate portion or the scar resulting from abscission of the staminate flowers); 3. spike width (at middle of pistillate portion of flowering spike); and 4. pistillate spike length (length of pistillate portion of flowering spike). Samples (excised from the pistillate portions of the inflorescences) were deposited in numbered vials. In the laboratory, the samples were removed from the vials in random order and examined under a binocular dissecting scope (×30), for 1. stigma shape; 2. gynophore hair apices—shape and pigmentation; and 3. bract presence or absence. Wet mounts of eased-out materials were viewed under the compound microscope (×100).

The scored microscopic floral characters (Table 1) revealed the following sets of correlations: (A) a linear stigma (Fig. 1) in consort with a flat spatulate-tipped bract (Fig. 2), and gynophore hair apices (Fig. 3) that are clubbed and pigmented; (B) a lanceolate-spatulate stigma (Fig. 4) in consort with a bract (Fig. 5) that is always narrower than the stigma, and gynophore

TABLE 1. Microscopic Characteristics: Correlations.

	Sample Number	Stigma	Bract	Hair apices
Set A	1, 2, 5, 6, 8, 11, 17, 18, 19, 20, 21, 22, 25, 26, 28, 29, 32, 33.	Linear	Flat Spatulate	Clubbed Pigmented
Set B	4, 9, 10, 24, 30.	Lanceolate- spatulate	Narrow	Clubbed non- Pigmented
Set C	3, 7, 12, 13, 14, 15, 16, 23, 27, 31, 34-40.	Broad	Absent	Linear non- Pigmented

hair apices (Fig. 6) that are clubbed but nonpigmented; and (C) a broad stigma (Fig. 7) in consort with the *absence* of a bract, and gynophore hair apices (Fig. 8) that are linear and nonpigmented. These three sets of correlations (A, B, and C) embody the salient and diagnostic floral characteristics of *Typha angustifolia* T. \times *glauca* and *T. latifolia*, respectively (Smith 1967).

With the numbered samples and hence the plants under study identified to species, it was possible to assess the reliability of the characters (leaf width, spike interval, pistillate-spike width, and pistillate-spike length) which have long been used for field identification. According to our field measurements (Table 2), the overlap in leaf width among *Typha angustifolia*, *T. \times glauca*, and *T. angustifolia* precludes this character as a basis for positive identification. The character most often relied on for field identification is spike interval. Our data (Table 2) indicate that while *Typha latifolia* (range 0-4 mm) may be distinguished easily from *T. angustifolia* (range 7-60 mm) and *T. \times glauca* (range 12-48 mm), the latter two cannot be separated using spike interval. Similarly, the data (Table 2) suggest that pistillate spike width is a fairly reliable character to separate out *Typha latifolia* (range 20-32 mm) from *T. angustifolia* (range 15-22 mm) and *T. \times glauca* (range 15-23 mm) but not to distinguish between the latter two. Hotchkiss & Dozier (1949) suggested that pistillate spike length may be a useful field character. Our data (Table 2), however, show too much overlap among the ranges of the three taxa to make this a valid criterion.

The presence versus absence of leaf sheath auricles is used by Voss (1972) in his key to *Typha angustifolia* and *T. latifolia*. We inadvertently restricted our observations to a few upper cauline leaves and thus failed to make a thorough study of this character. Smith (1967), however, found that the leaf sheath auricles of *Typha \times glauca* run the gamut from absent to well developed. The character therefore is too variable to be diagnostic in distinguishing the hybrid from its parents.

In summary, we concluded that the field identification characters of spike interval and pistillate spike width may be used with some degree of reliability to tentatively separate *Typha latifolia* from *T. angustifolia* and the



FIG. 1-3. *Typha angustifolia*. 1. Pistil showing ovary, style, and stigma, $\times 2$. 2. Spatulate bract, $\times 2$. 3. Clubbed, pigmented gynophore hair apex, $\times 25$. FIG. 4-6. *T. glauca*. 4. Pistil showing ovary, style, and stigma, $\times 3$. 5. Linear-spatulate bract, $\times 4$. 6. Clubbed non-pigmented gynophore hair apex, $\times 20$. FIG. 7-8. *T. latifolia*. 7. Pistil showing ovary, style, and stigma, $\times 10$. 8. Linear non-pigmented gynophore hair apex, $\times 30$. (Drawings by M. L. Salim).

TABLE 2. Field Character Measurements (mm).

Sample Number	Leaf Width	Spike Interval	♀ Spike Width	Spike Length
1	7	25	17	145
2	9	36	16	195
5	8	31	15	156
6	6	41	15	145
8	7	44	17	135
11	7	19	18	174
17	8	29	17	157
18	7	49	17	183
19	6	32	18	143
20	6	15	19	145
21	7	45	15	175
22	7	41	18	142
25	6	11	16	144
26	8	7	16	170
28	9	60	22	138
29	8	40	16	159
32	7	45	17	122
33	8	52	17	134
<i>(T. angustifolia)</i>	Range 6-9	Range 7-60	Range 15-22	Range 122-195
	\bar{X} 7.3	\bar{X} 34.6	\bar{X} 17	\bar{X} 153.4
	s.d. 0.9	s.d. 14.3	s.d. 1.6	s.d. 18.7
4	9	12	23	186
9	6	30	15	125
10	6	30	16	123
24	9	48	20	159
30	7	45	20	109
<i>(T. glauca)</i>	Range 6-9	Range 12-48	Range 15-23	Range 109-186
	\bar{X} 7.4	\bar{X} 33.0	\bar{X} 18.8	\bar{X} 140.4
	s.d. 1.4	s.d. 12.9	s.d. 2.9	s.d. 28.1
3	9	1	20	134
7	9	0	25	140
12	9	4	27	169
13	10	0	32	138
14	9	0	31	130
15	9	0	30	141
16	10	0	22	190
23	8	0	31	147
27	9	0	31	144
31	7	0	22	133
34	8	0	24	154
35	8	0	29	116
36	11	0	29	180
37	8	0	25	173
38	9	0	24	125
39	10	0	30	119
40	8	0	22	143
<i>(T. latifolia)</i>	Range 7-11	Range 0-4	Range 20-32	Range 116-190
	\bar{X} 8.9	\bar{X} 0.3	\bar{X} 26.7	\bar{X} 145.6
	s.d. 1.0	s.d. 1.0	s.d. 3.8	s.d. 20.6

hybrid, but microscopic floral characters should be used to confirm the identification. To positively identify *Typha angustifolia* and *T. × glauca* microscopic floral characters *must* be used. Thus we determined that *Typha angustifolia*, *T. latifolia* and the putative hybrid *T. × glauca* are all present in Genesee County. We have deposited specimens in the Herbarium of the University of Michigan, Ann Arbor (MICH).

Of the 40 specimens examined, 45% were *T. angustifolia*, 42.5% *T. latifolia*, and 12.5% *T. × glauca*. More than one taxon was present at 47% of the sites. These percentages provide a baseline figure that has continuing significance for the future. Lee (1975) in his study of introgression of North American *Typha* has presented compelling evidence for a pattern of introgression towards *T. angustifolia* and the lack of gene flow towards *T. latifolia*. With the many disrupted habitats in Genesee County it is tempting to conclude that the presumably once common *Typha latifolia* is giving way to the formerly rare *T. angustifolia* because of eutrophic and more polluted marshes.

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RARE PLANTS OF WISCONSIN POINT,
DOUGLAS CO., WISCONSIN [1]

County
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Koch, Younger & Bruederle (1983) recently provided an excellent overview of the vegetation of Wisconsin Point, a narrow sand peninsula in the Superior harbor in extreme northwestern Wisconsin. Two rare species, *Thalictrum confine* Fern. and *Ribes oxyacanthoides* L., were noted as not seen at the site since the 1940's. Field searches in 1979 and 1980 by myself and other botanists with the Scientific Areas Section of the Wisconsin Dept. of Natural Resources have verified the persistence of these populations on Wisconsin Point.

The putative *T. confine* was re-identified in 1980 by Bernard Boivin as *Thalictrum venulosum* var. *turneri* Boivin. Hundreds of individuals occur along the open margins and in the partially shaded interior of the mixed white pine-red pine-paper birch forest. Although this species seems very rare in Wisconsin, it is not currently protected by law, as further field work is needed to determine its status at other sites.

Ribes oxyacanthoides, Hawthorn-leaved Gooseberry, occurs in an open stand of *Populus balsamifera*, *Ribes americanum*, and *Sambucus canadensis*. The population is small (ca. 35 individuals) but appears to be healthy. This species, known at one other site in Wisconsin (Alverson & Solheim, 1983), is listed as threatened in Wisconsin.

A third rare species, *Parnassia palustris* L., the Marsh Grass-of-Parnassus, occurs by the thousands in the dune slack community, as mentioned by Koch *et al.* It is listed as threatened in Wisconsin.

I wish to repeat the previous authors' emphasis on the need for protection of Wisconsin Point from overuse by the public, lest these and other native plant populations be severely damaged or lost.

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WINTER TAXONOMY CLASS MATERIALS
AT THE UNIVERSITY OF MINNESOTA, ST. PAUL 1-3-74

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Introductory plant taxonomy is offered from January through mid-March at the University of Minnesota, St. Paul, in order to precede an advanced course offered in spring and to provide good balance for the departmental courses over the school year. The laboratory part of the course requires material of ferns, gymnosperms, and about 30 common angiosperm families, with abundant additional material for keying practice using the local spring flora (Morley, 1966) as the text. For maximum student interest as much live flowering material as possible is provided, not an easy task during a Minnesota winter.

The plant material for such a course must be reliable, easy to handle, and adaptable to the chronological sequence of the course. Using the work of Rosendahl (1914), Pohl (1964), and Mellichamp (1976a, b) as initial guides, we have developed through experimentation a fairly satisfactory list of materials, which we report on here. Trials with the material were begun in the winter of 1974-75, at which time the greenhouse manager was Mr. Robert Montgomery; Ms. Sladky took over this position in mid-1977. The course was first offered in the winter of 1976-77. The present report is therefore based on eight years' experience with the course materials.

In order to provide full coverage of plant groups and relate the course to the state flora a great deal of special material must be grown or forced, much of it consisting of native or naturalized plants. This paper is addressed to these special materials, most of which are uncommonly grown in the greenhouse or are used here in an uncommon manner. We also use many standard easily grown plants which are listed at the end of this paper.

The special materials include plants grown from seed, winter annual rosettes, edible roots, perennial herbs, shrubs, and forced branches. Of the herbaceous plants it is generally the weedy and aggressive ones that are most easily grown, although some species of this type will not bloom in the lighting conditions available. The use of shrubs has proved a very successful addition to winter materials: we force small potted ornamental shrubs for this purpose.

A schedule of starting dates is drawn up in fall in order to bring each plant into flower when needed, since most of the plants bloom over a relatively short period. The special plants will now be considered in turn.¹

¹Some of the data in the tables were obtained with the help of R. Montgomery.

PLANTS FROM SEED

These are all annual or winter-annual weeds (Table 1).² Seeds of some, such as *Thlaspi arvense*, need a dry resting period before they will germinate well. Seedlings of certain plants like *Thlaspi arvense* and *Crepis tectorum* form rosettes which do not always bolt under our greenhouse conditions. Therefore we raise more than we need of these, hoping to get enough flowering plants for use. Several species being tried for suitability formed rosettes but never bolted, and seed of some others never germinated satisfactorily (see below Table 1).

We collect the seed at local sites or in the greenhouse. The seed is stored dry in airtight containers at 40°F. Then we sow it usually without stratification, scarification, or other treatments in flats of vermiculite. The seed is lightly covered with vermiculite and placed over bottom heat of about 76°F until germination. Experimentation with seed treatments, particularly stratification, has been minimal. Further trials might yield better results in species we have failed to germinate successfully.

Our seedlings and all potted plants are grown in a greenhouse lighted by HID (high-intensity discharge sodium) lamps, although owing to a shortage of space most of our plants are not placed directly beneath the lights. The lights are set for a 16-hour day. Air temperature in the room varies from about 75°F in the day to 65° at night.

TABLE 1. Plants from seeds.

Species	No. of trials	Date sown	Days to full bloom	Comments
<i>Brassica kaber</i>	1	23 Nov.	113	
<i>B. nigra</i>	1	14 Nov.	122	
<i>Capsella bursa-pastoris</i>	1	8 Dec.	100	
<i>Chenopodium album</i>	1	22 Dec.	87	
<i>Crepis tectorum</i>	6	7 Nov.–1 Jan.	79–127	Sometimes only a few plants bolt.
<i>Erysimum cheiranthoides</i>	5	28 Nov.–1 Jan.	65–84	Good when seeds are stratified 1 month at 40°F.
<i>Lepidium</i> sp.	1	1 Jan.	89	
<i>Matricaria matricarioides</i>	1	1 Jan.	105	
<i>Sonchus oleraceus</i>	2	30 Oct., 15 Nov.	107, 124	Good
<i>Thlaspi arvense</i>	3	1 Nov.–1 Jan.	57–95	Failed to bolt 1 year

Species which gave poor results: *Alliaria petiolata* (no germination); *Berteroa incana* (leaves only); *Cardamine pensylvanica* (poor germination); *Cynoglossum officinale* (few grew, no flowers); *Descurainia pinnata* (leaves only); *Lappula echinata*; *Lychnis alba*; *Silene cserei* (leaves only); *Sisymbrium altissimum* (leaves only); *Sisymbrium loeselii* (leaves only); *Veronica peregrina* (few flowers).

²In the tables, when the number of trials was 3 or more, only the earliest and latest dates of initiation are given in the second column.

WINTER ANNUAL ROSETTES AND EDIBLE ROOTS

The winter annual rosettes must be dug every fall from nearby fields or other weedy areas. They generally bloom reliably, although *Capsella* failed once (Table 2). The edible roots we use are those of turnips and carrots, forced for flowering by potting in coarse vermiculite and placing in the greenhouse. Turnips ordinarily are highly satisfactory, but one must search for unpared unwaxed roots with the crown buds still present. Some turnips fail in any event, our percent loss being about 25%, and occasionally few of those that grow produce flowers. The flowers must be hand-pollinated to get fruits. With carrots we experienced about a 30% loss, and blooming time is much more variable and unpredictable than with turnips. Consequently we start them at intervals in order to bracket the desired blooming time.

TABLE 2. Winter rosette transplants and edible roots.

Species	No. of trials	Starting dates	Days to full bloom	Comments
<i>Brassica rapa</i>	4	11 Dec.–11 Jan.	39–57	Good
<i>Capsella bursa-pastoris</i>	4	29 Dec.–11 Feb.	20–34	Generally reliable, failed to bolt in 1982
<i>Centaurea maculosa</i>	1	27 Jan.	62	
<i>Daucus carota</i>	3	26 Nov.–10 Dec.	73–115 to 1st plant to bloom	Larger thicker carrots work best; look for organic bulk ones.
<i>Ranunculus abortivus</i>	4	27 Nov.–13 Dec.	42–64	Reliable
<i>Thlaspi arvense</i>	3	5–7 Jan.	20–30	Reliable

PERENNIAL HERBS AND SHRUBS

The perennial wildflowers and ornamental shrubs are taken outside as soon as possible in spring following their class use in winter. We move them when night temperatures are consistently above 25°F. The pots are sunk to their rims in a bed of wood chips (used for ease of pot removal in late fall). A cold frame would also be a suitable "over-summering" location. The potted winter annual rosettes are added in fall. All plants are moved to a lighted 40°F cold room in mid-November both to avoid all danger of freezing damage and to eliminate the difficulty of finding plants under snow. We try to get the plants inside before the night temperatures fall below 20°F. In a milder climate or in a cold frame, the plants could conceivably remain outdoors until scheduled for forcing in the greenhouse.

Rosendahl (1914) made no mention of danger from extreme cold, even though he left his plants to freeze thoroughly in December and gave no indication that he sank his containers in the ground or otherwise protected

them. However, in the first two years of work with the present course the pots were left exposed on the surface, and then plants were sometimes lost to freezing when temperatures dropped unexpectedly into the 5°F range (Table 3). Natives as well as introductions were lost. Soil temperatures at a depth of 5 cm sometimes drop as low as -7°F at the St. Paul weather station, although they are usually much warmer. Consequently we remove the sunken pots as a precaution before extreme cold sets in, even though the wood chips would probably provide adequate protection.

We try to keep our perennials as many seasons as possible. Some do not maintain themselves well when forced year after year and need alternate years of rest or occasional replacement. Most are transplanted about every second year; most require ample pot room. We prefer to purchase the natives from a nursery that propagates these plants but have collected judiciously from abundant native populations at times.

TABLE 3. Potted perennial herbs and shrubs.

Species	No. of trials	Date to greenhouse	Days to full bloom	Comments
<i>Achillea millefolium</i>	7	29 Dec.-11 Feb.	48-109	Reliable
<i>Actaea rubra</i>	1	29 Jan.	26	Good
<i>Anemone virginiana</i>	1	8 Nov.	120, 135	
<i>Aquilegia canadensis</i>	7	16 Nov.-16 Dec.	35-64 (-92)	Reliable
<i>Arisaema triphyllum</i> *	2	18, 19 Jan.	34, 36	Good
<i>Asarum canadense</i>	6	20-27 Dec.	35-48	Reliable
<i>Berberis thunbergii</i>	2	8 Jan.-21 Feb.	18-22	Poor
<i>Carex granularis</i>	1	22 Jan.	80	
<i>C. laxiflora</i> *	1	12 Feb.	46 (fruit)	
<i>C. sprengelii</i>	1	22 Jan.	47	
<i>Caulophyllum thalictroides</i> *	1	23 Dec.	21	Few flowers
<i>Euphorbia esula</i>	1	6 Feb.	31	
<i>Forsythia Karl Sax</i>	1	17 Jan.	19	
<i>Glechoma hederacea</i> *	1	9 Dec.	21	
<i>Hepatica acutiloba</i>	1	6 Jan.	22	Good
<i>H. americana</i>	3	6, 7 Jan.	21, 22	Good
<i>Hydrophyllum virginianum</i> *	5	22 Dec.-8 Jan.	49-61	Reliable
<i>Lamium album</i>	5	25 Jan.-10 Feb.	32-46	Good**
<i>Leonurus cardiaca</i> *	4	19 Jan.-12 Feb.	54-66	Good**
<i>Lonicera xylosteum</i> , Clavey's Dwarf	1	26 Jan.	28	Good
<i>Malva neglecta</i> *	1	28 Dec.	77	Few Flowers
<i>Osmorhiza longistylis</i> *	5	2 Dec.-28 Jan.	35-56	Needs large pot
<i>Panicum oligosantes</i> *	1	21 Dec.	67	
<i>Phlox divaricata</i>	3	14 Dec.-22 Jan.	35-38	Good
<i>Plantago lanceolata</i>	1	28 Jan.	48	
<i>Polygonatum pubescens</i>	2	24 Dec., 15 Jan.	45, 46	Good

TABLE 3. (Continued)

Species	No. of trials	Date to greenhouse	Days to full bloom	Comments
<i>Potentilla argentea</i> *	7	23 Dec.–18 Feb.	45–55(–67)	Good. Does well when kept in greenhouse and moved to cold room in Oct.
<i>P. tridentata</i>	3	12 Jan.–21 Feb.	55	Repot frequently
<i>Ranunculus septentrionalis</i>	1	11 Dec.	46	Good but few flowers
<i>Ribes alpinum</i>	6	1–15 Feb.	17–26	Very good
<i>Sanguinaria canadensis</i>	3	13, 14 Jan.	15	Good but petals drop soon
<i>Scilla sibirica</i>	6	31 Jan.–25 Feb.	7–9(–17)	Reliable
<i>Smilacina racemosa</i>	5	2 Dec.–10 Jan.	40–58(–86)	Good
<i>S. stellata</i> *	3	14–28 Jan.	34	Good
<i>Solanum dulcamara</i> *	5	1–15 Feb.	40–61	Good
<i>Spiraea arguta</i>	5	24 Jan.–28 Feb.	10–16	Very good
<i>S. van houttei</i>	1	8 Jan.	33	
<i>Taraxacum officinale</i>	1	1 Jan.	22	
<i>Thalictrum dioicum</i>	4	26 Dec.–11 Jan.	28–30	Good
<i>T. venulosum</i>	4	20–28 Dec.	31, 32	Good
<i>Uvularia grandiflora</i>	2	12 Jan., 8 Feb.	22, 23	Good
<i>Viola cf. cucullata</i>	2	4, 5 Jan.	38	
<i>V. rugulosa</i>	1	22 Dec.	38	

*Killed by freezing 1976–77 or 1977–78. In addition, *Plantago major* and *Vicia americana* were freeze-killed before their forcing times could be determined.

***Lamium album* and *Leonurus cardiaca* are cut back and cleaned of old leaves twice, before being moved outside in spring and when moved into the cold room in fall.

FORCED CUT BRANCHES

The forced branches we try to handle as efficiently as possible. They are not soaked before forcing, as recommended by some. After collecting, the twigs are re-cut immediately before immersing in jars of warm water. The jars are placed in a cool greenhouse with 70° days and 60°F nights. No additional lights are used in most cases, although daylength may be influenced by light from the adjacent greenhouse, which has artificial lights set for a 16-hour day. The water in the jars is changed weekly by flushing them out, without removing the branches. For about two seasons we placed the branches in a floral preservative, such as Floralife or Oasis. These solutions appear to benefit some plants, hinder others (Table 4), and make little difference to still others. We have given up the general use of preservatives but use them selectively and are still making comparisons to determine which plants gain from their use.

As Mellichamp (1976b) and others have pointed out, humidity is an important factor in successful forcing of branches. Dry conditions generally yield poor results. However, some plants are more consistent, require less

attention, and bloom well under drier conditions than others. Plants of this type mostly have rather stout twigs and bloom before the leaves appear (Table 4). Species of *Salix* that strike roots rapidly are also very reliable.

Minnesota winters are very dry, and considerable heat is needed in the greenhouse, making it difficult to maintain humid conditions even though the greenhouses are wetted twice daily. For the first seven years we forced all branches in the open greenhouse, wetting the branches twice daily with tempered tap water, and had fair success. However, we have now constructed a humidity chamber of polyethylene sheeting stretched around a light frame built on part of a greenhouse bench. Inside this we place the branches whose development we know to be most endangered by dry air. The chamber is very effective. Male *Salix discolor* flowers freely in it, whereas this plant never bloomed for us on the open bench. *Ribes americanum* bloomed freely and formed many roots when inside, while flowering sparsely and forming no elongate roots when outside. Flowering times are usually about the same inside as outside but sometimes lag in the chamber as much as six days. On sunny days the chamber will become warmer than the open bench; warm temperatures are tolerated as long as the humidity remains high, but the chamber should not be allowed to become hot. The enclosure can be ventilated for cooling, and a shade could be provided although we have not done so. Branches inside should be wetted once or twice daily; as long as the inner walls of the chamber are covered with condensation droplets the humidity is high enough.

In the absence of a humidity chamber, branches that are very sensitive to dry conditions can be aided by shading from the direct sun. Shade can be provided by hanging a sheet of black plastic next to the branches, since the sun is low at this time of year. In some cases shade may give better results than the humidity chamber.

Experiments with *Caragana arborescens* and *Salix discolor* suggest that the performance of difficult species may be improved slightly by recutting the stem bases every four or five days. Mashing the stem bases of *Salix discolor* twigs, on the other hand, brought no change. Forcing branches on a mist bench receiving a fine spray eight times an hour during the day and four times an hour at night permitted development of a few more buds than otherwise; however, development was slowed apparently due to the evaporative cooling effect, and the leaves and flowers were very subject to wilt when the branches were removed from the bench.

External variables beyond control cause forcing times to vary from year to year even with the same plants, as pointed out by Mellichamp (1976a, b). The number of days in the 40° range controls the fulfillment of the chilling requirement of the plants (Dr. H. Wilkins, personal communication). If fall and early winter have more 40° days than usual, forcing times for branches may be reduced that year. Within the greenhouse, the number of sunny and cloudy days affects growth.

TABLE 4. Forced cut branches.

Species	No. of trials	Date to greenhouse	Days to full bloom*	Comments
<i>Acer negundo</i> ♂ + ♀	8	16 Jan.–21 Feb.	18–41	Reliable
<i>A. saccharinum</i> **	8	23 Jan.–1 Mar.	4–12	Good, aided by floral preservative
<i>Alnus rugosa</i> **	4	13–17 Jan.	10–14	Catkins don't always expand fully.
<i>Amelanchier</i> sp.	4	5 Feb.–2 Mar.	18–19	Fair, good in shade or humidity chamber.
<i>Betula papyrifera</i>	5	22–28 Dec.	36–39	Good.
<i>B. pendula</i>	1	9 Jan.	30	
<i>Caragana arborescens</i>	2	17, 21 Feb.	15, 28	Poor, unreliable
<i>C. frutex</i>	1	6 Mar.	30	Humidity chamber, few flowers.
<i>Celastrus scandens</i>	1	31 Jan.	45	Few flowers
<i>Cercis canadensis</i>	1	15 Jan.	20	Unreliable, often fails
<i>Chamaedaphne calyculata</i>	3	19 Feb.–6 Mar.	16–19	Didn't bloom freely Hindered by floral preservative
<i>Cornus stolonifera</i>	1	7 Feb.	45	Often fails
<i>Forsythia</i> × <i>intermedia</i> **	4	4–9 Feb.	10–15	Branches must come from plant in sheltered place
<i>Fraxinus pennsylvanica</i> ♂**	6	8–12 Feb.	9–14	Good
<i>Lonicera tatarica</i>	4	21 Jan.–7 Feb.	30–35	Few flowers
<i>Magnolia soulangeana</i>	1	15 Jan.	18	Good
<i>Malus</i> cv Hopa	6	17–26 Jan.	25–31	Good. Best in shade
<i>Ostrya virginiana</i>	1	22 Jan.	39	
<i>Populus deltoides</i> ♂**	9	19 Jan.–16 Mar.	10–25	Good
<i>P. deltoides</i> ♀	1	24 Jan.	22	
<i>P. tremuloides</i> ♂**	6	24 Jan.–13 Feb.	6–9	Good
<i>Prunus americana</i>	5	27 Jan.–14 Feb.	20–33	Good, best with floral preservative
<i>P. domestica</i>	1	25 Jan.	21	Few flowers
<i>P. tomentosa</i>	7	18–27 Feb.	10–15	Good, best in shade
<i>Quercus macrocarpa</i>	7	1–22 Jan.	24–35	Male catkins fair, hard to get female fls, best in humidity chamber
<i>Ribes alpinum</i>	3	15–21 Feb.	21–26	Fair
<i>R. americanum</i>	2	27 Jan., 16 Feb.	33–40	Fair, good in humidity chamber
<i>R. odoratum</i>	7	20 Jan.–18 Feb.	17–25	Good, needs shade
<i>Salix bebbiana</i> ♂	6	6 Jan.–13 Feb.	18–28	Fair, good in humidity chamber
<i>S. fragilis</i> ♂	1	22 Jan.	28	
<i>S. discolor</i> ♀	4	11 Feb.–12 Mar.	7–16	Fair, good in humidity chamber
<i>S. discolor</i> ♂	1	5 Feb.	11	Humidity chamber only

TABLE 4. (Continued)

Species	No. of trials	Date to greenhouse	Days to full bloom*	Comments
<i>S. amygdaloides</i> ♂**	5	18 Feb.–5 Mar.	15–23	Good, strikes roots
<i>S. lucida</i> ♂**	7	11–26 Feb.	19–27	Very good, strikes roots
<i>Sambucus pubens</i>	2	24 Jan., 6 Mar.	25, 19	Needs shade, unreliable
<i>Shepherdia argentea</i> **	6	5 Feb.–5 Mar.	7–10	Very good
<i>Spiraea arguta</i>	1	5 Feb.	25	Poor
<i>Staphylea trifolia</i>	9	6 Feb.–22 Mar.	20–27(–34)	Good, best in humidity chamber, hindered by floral preservative
<i>Ulmus americana</i> **	6	10 Jan.–6 Feb.	6–13	Good; watch for diseased branches.
<i>Xanthoxylum americanum</i> **	7	22–31 Jan.	16–20	Good

*In any one year, branches collected later in winter will usually bloom in less time than those collected earlier.

**Species most reliable on the open bench.

Species that gave unsatisfactory results: *Berberis thunbergii*, *Cotoneaster lucida*, *Morus alba*, *Physocarpus opulifolius*, *Prunus virginiana*, *Quercus alba*, *Rhamnus cathartica*, *Ribes missouriense*, *Robinia pseudoacacia*, *Spiraea vanhouttei*, and *Viburnum trilobum*. None of these were tried in the humidity chamber.

In addition to the preceding special plant materials, the following plants commonly grown in the greenhouse are utilized: *Agapetes serpens*, *Anchusa* cv. Blue Angel, *Anoda cristata*, *Anthurium scandens*, *Antirrhinum majus*, *Asclepias curassavica*, *Borago officinalis*, *Capsicum frutescens*, *Cattleya* hybrids, *Chrysanthemum* cultivars, *Cyclamen persicum*, *Cyperus alternifolius*, *Cytisus racemosus*, *Dianthus chinensis*, *Euphorbia splendens*, *Fagopyrum esculentum*, *Freesia* × *hybrida*, *Fuchsia* cultivars, *Helianthus annuus*, *Kalanchoe diagremontiana*, *Lobularia maritima*, *Matthiola longipetala*, *Michelia figo*, *Nicotiana alata*, *Oncidium* spp., *Ornithogalum caudatum*, *Neomarica gracilis*, *Paphiopedilum* cultivars, *Pentas lanceolata*, *Petunia* cultivars, *Primula malacoides*, *Rhododendron* cultivars, *Saponaria officinalis*, *Scilla violacea*, *Senecio cruentus*, *S. fulgens*, *Setaria palmifolia*, *Viola tricolor*, and *Zantedeschia aethiopica*. In addition, cut flowers from a local florist's supplier are occasionally utilized. Finally, preserved or frozen flowers of several species supplement the living material when necessary.

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PLATANThERA \times VOSSII, A NEW NATURAL
HYBRID ORCHID FROM NORTHERN
LOWER MICHIGAN [J.W.]

lv
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To my knowledge, no hybrid between *Platanthera* (*Habernaria*) *clavellata*, the club-spurred orchid, and other native platantheras has been reported. One might not, perhaps expect such hybrids as Correll, (1950) and Luer (1975) report *P. clavellata* to be self-pollinating. Indeed, almost every flowering plant encountered in the wild sets seed pods in all its ovaries unless it has been damaged. Such behavior is often seen in self-pollinating species.

Several times over the past 30 years, my wife and I have found specimens of *P. blephariglottis*, the white-fringed orchid, which due to frost damage or other injury produced greenish, deformed flowers suggesting that they might have resulted from a cross between *P. clavellata* and *P. blephariglottis*. In all cases, however, the plants proved to be abnormal *P. blephariglottis*. The possibility of a *P. blephariglottis* \times *P. clavellata* hybrid piqued our imaginations, and we have been on the lookout for it every year in the many suitable open bogs near the tip of Michigan's Lower Peninsula. While exploring an open sphagnum bed in a tamarack-black spruce bog in southern Otsego County on August 8, 1982, we came across two unusual platantheras in a mixed colony of *P. blephariglottis* and *P. clavellata*. At first glance, these plants, too, appeared to be abnormal *P. blephariglottis*, for they were nearly as large, and the flower color was almost white. But on close examination, their hybrid nature was quite apparent. The plants were almost exactly intermediate between both parents in many features of floral structure and lip carriage, color, and number of flowers, while favoring the *P. blephariglottis* parent in overall size. The two plants, growing close together, and essentially identical, probably represent clonal offsets of a single hybrid plant. Since there are no other platanthera species in the bog (which is surrounded by cultivated fields), there can be little doubt as to the hybrid nature or the parentage of these plants. We collected one stem as a herbarium voucher and left the other undisturbed in the bog.

In keeping with the custom of naming natural orchid hybrids, I am pleased to name this hybrid for Edward G. Voss for his distinguished work on the Michigan flora and his important contributions to the exploration and knowledge of the botany of the Great Lakes region.

Platanthera \times **vossii** hybrida nova.—Hybrida nova inter *P. blephariglottis* et *P. clavellata*, caule succulento 39 cm alto, caule *P. blephariglottis* graciliore, foliis et bracteis flavovirentibus, foliis et bracteis *P. blephariglottis*

minus glaucis, folio secundo quam primo parviore, vaginanti caulem ut in *P. clavellata*, foliis aliis bracteiformibus, floribus viridi-albis, portatis ut in *P. clavellata* anfractu ovarii, labello truncato fere albo late cuneato breviter fimbriato recurvo ut in *P. clavellata*, calcari gracili ovario longiore, virello conspicue clavellato curvo sursum in $\frac{1}{3}$ distali ut in *P. clavellata*.

Stems 39 cm tall, fleshy but more slender than in *P. blephariglottis*, narrowly and weakly winged below. Lower leaf linear-lanceolate, acuminate, keeled below and with the proximal portion sheathing the stem, the blade 8.5 cm long, 1.7 cm wide. Second leaf smaller, as in *P. clavellata*, sheathing the stem, the blade linear-lanceolate, 5 cm long, 6 mm wide. Remaining leaves sharply reduced, bractlike, linear, 1.7 cm \times 2 mm and 1.3 cm \times 1 mm, respectively. Leaves and bracts yellow-green, less glaucous than in *P. blephariglottis*. Floral bracts linear-lanceolate, acuminate, the lowermost 11 \times 1 mm, shorter than the sessile ovaries. Ovary of the



Figs. 1-3. Details of the hybrid and its putative parents. 1. *Platanthera blephariglottis*. 2. *P. clavellata*. 3. *P. x vossii*.



Fig. 4. *Platantthera* \times *vossii*, type. Note the influence of the *P. clavellata* parent in the fewer flowers held at an angle that is not fully resupinate as in most members of the genus, the clavellate spur, and the convex-recurved lip with its truncate, barely fringed apex. The size, coloring, and overall stature show a strong *P. blephariglottis* influence.

lowest flower, at anthesis, 1.6 cm long, twisted, slender. Flowers 8, white, tinged green, carried (as in *P. clavellata*) almost 45° askew from the lip-lowermost position of most platantheras. Dorsal sepal of lowermost flower concave, widest at about the middle, 5 mm long, 2.5 mm wide, greenish-white. Lateral sepals spreading, greenish-white, 4 × 3 mm, asymmetrically ovate. Petals narrowly ovate, obscurely erose-fringed distally, 4 × 9 mm, greenish-white. Lip 5–6 mm long, 4–5 mm wide, nearly white, broadly cuneate, upper surface convex, recurved (as in *P. clavellata*) with a distally directed, short, sparse fringe. Apex of the lip broadly truncate and irregularly tridentate, with an irregular fringe up to 0.5 mm long. Spur longer than the ovary, slender, conspicuously clavellate, 1.5–1.6 cm long, curved upward in its distal one-third (as in *P. clavellata*), greenish.—See figs. 1–4.

TYPE: *Sphagnum-Chamaedaphne* mat in *Larix-Picea* bog, Otsego County, Michigan, F. W. & R. Case, August 8, 1982 (MICH).

P. ×vossii is remarkably intermediate between its putative parents (see figure 1). While it favors the *P. blephariglottis* parent in overall size and leaf shape, its single large leaf, and the reduced second leaf, and the much smaller bract-like ones higher on the stem give to the plant the overall aspect of the *P. clavellata* parent. The few flowers nearly as large as in the white-fringed parent, but greenish-tinted and intermediate in shape, also show their relationship to *P. clavellata* in their peculiar “askew” carriage and convexity. The spur, shorter than the tapered-acuminate spur in *P. blephariglottis*, is conspicuously clavellate and upward-curved in the manner of *P. clavellata*.

The bog in which Voss’ platanthera grows is typical of the small, rather open spruce-tamarack bogs common in the region. The lush sphagnum mat supports numerous sedges and such orchids as *Arethusa bulbosa*, *Calopogon tuberosus*, *Pogonia ophioglossoides*, *Malaxis unifolia*, and *Cypripedium acaule*, as well as *Drosera rotundifolia*, *Sarracenia purpurea*, *Chamaedaphne calyculata*, *Kalmia polifolia*, *Vaccinium oxycoccos*, *Ledum groenlandicum*, and *Andromeda glaucophylla*.

Considering that both parents frequently grow together in open bogs in northern Michigan, Ontario, the Maritime Provinces, and (abundantly so) in Newfoundland and they also grow in reasonable proximity in the North Carolina mountains, it is surprising that this hybrid has not been encountered before now.

I am grateful to A. Reznicek and E. G. Voss for critically reading this manuscript. To John Freudenstein for writing and W. R. Anderson for checking the Latin description I give my thanks.

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24/9
RICCIACEAE IN MICHIGAN [J]

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The discovery of six species of liverworts belonging to the genus *Riccia* new to Michigan resulted from collections made in southern Michigan from November 21 to December 7, 1981. The many new reports made here were made possible by an "explosion" of Ricciaceae during an unusually wet and warm fall. Farmers had been unable to grow crops in parts of their fields because of flooded spring conditions. There was twice as much precipitation as normal between April and October. September rains were more than three times the average. Even in November, when we first discovered an abundance of Riccias in the fields, there were still flooded areas. In every likely looking field we encountered Riccias, sometimes in enormous populations, in open, exposed sandy areas, along tire tracks and ruts, and on the sides of grassy hummocks. The soil was dark, indicating the presence of organic matter. Fallow corn and soybean fields and edges of active winter wheat fields were ideal. The Riccias occurred in various combinations with *Ricciocarpus*, various mosses, several genera of hornworts, and *Astrella*. Associated invasive seed plants included natives (*Ambrosia artemisiifolia*, *Cerastium arvense*, *Cyperus rivularis*, *Datura stramonium*, *Eleocharis* sp., *Fragaria virginiana*, *Oenothera biennis*, *Panicum capillare*, *Plantago rugelii*, *Ranunculus sceleratus*, and *Xanthium strumarium*) and exotics (*Chenopodium album*, *Lychnis alba*, *Rumex crispus*, *Setaria glauca*, and *Solanum nigrum*).

The habitats were all located near the junction of Monroe, Washtenaw, and Wayne Counties. Soils associated with the Riccias were sands developed from glacial outwash and old lake bottom plains, of the Oakville-Granby-Tedrow association, showing a slightly acid to neutral reaction (Bowman, 1981). These rapidly draining soils usually show no tendency to flood but have seasonally high watertables (near the surface), with exception of the Oakville soils that occur on the ridges.

The appearance of Riccias appears to be related to seasonal flooding and/or high water tables. In normal or dry years the incidence of Riccias is considerably less, although we can expect to find them at any time that heavy rains occur during spring, summer, or fall. For example, one collection of *R. beyrichiana* was made 28 May (64026)¹ and another 1 August (82014). The rainfall in this area is usually fairly evenly distributed with ca. 58% of it falling during the period April–September (Bowman, 1981).

¹Numbers quoted without collector in this paper are those of W. H. Wagner and have been deposited in the University of Michigan Herbarium.

Members of the Ricciaceae are poorly collected in Michigan. Previous reports of *Riccia* are confined to *R. fluitans* (Steere, 1940). *Riccia rhenana* is also attributed to Michigan (Woodfin, 1972), but our treatment follows the suggestion of Berrie (1964) and does not recognize this as separate from *R. fluitans*. The only other member of the family reported from the state is the cosmopolitan *Ricciocarpus natans* (Steere, 1940).

Previously collected in Monroe Co. (64026), and rediscovered during this investigation is *Riccia beyrichiana*. We now have new collections of this distinctive species from Monroe (81064) and also Wayne Cos. (81067a). Five other species new to the state are *R. arvensis*, Monroe (81061) and Wayne Cos. (81069); *R. canaliculata*, Wayne Co. (81068); *R. crystallina*, Monroe Co. (81062b); *R. hirta*, Monroe (81060), Washtenaw (81071), and Wayne Cos. (81067b); and *R. sullivantii*, Monroe (81087c) and Washtenaw Cos. (81072d).

Previous to this study all other parts of the Great Lakes area had more reports: Indiana 6 (Parker, 1938), Wisconsin 6 (Conklin, 1929), Ohio 3 (Miller, 1964), Minnesota 11 (Schuster, 1953), and Ontario 4 (Cain & Fulford, 1948). This in itself indicates that this group of plants has probably been underappreciated in Michigan and deserves more field investigation. The genus *Riccia*, to which the majority of species belong, is ecologically eccentric and taxonomically formidable. It is the center of taxonomic and phylogenetic controversy. The identification of species is highly technical, and species in the group have been overlooked by Michigan collectors. This is particularly unfortunate since so much of the basic biology, geography, and ecology of these plants needs further study. The need for studies on the habitat, distribution, and form of these species is undisputed.

Taxonomic concepts in the Ricciaceae are in a state of flux. Three genera are commonly recognized: *Riccia*, *Ricciocarpus*, and *Oxymitra*. In addition, some hepaticologists have recognized *Ricciella* with *R. fluitans* as the type. The nature and character of many species of *Riccia* are in question, especially as regards the *R. fluitans* complex. We treat *Ricciella* as a subgenus of *Riccia*, as do most current investigators and do not recognize *R. rhenana* ($n=16$) as separate from *R. fluitans*. ($n=18$), nor do we accept *R. duplex* ($n=16$) as distinct from *R. canaliculata* ($n=8$), following Berrie (1964).

The Ricciaceae are notably variable in gross morphology. Some species adapt to both inundation and drought. Such habits lead to problems in constructing a key based on gross morphology. Precise identification requires the study and measurement of spores; for details of spores the reader is referred to Frye & Clark (1937), Macvicar (1926), and Schuster (1953). Our key should prove useful for field identification and lead the reader toward the more technical literature as needed. The following principles of variation should be kept in mind whether using this or a more technical key: Most Riccias grow in full sunlight, but some may be shaded by adjacent vegetation. They exhibit sun/shade dimorphism, especially in the development of pigmentation. Shade plants commonly show little coloration. Schuster (1953) indicated that extreme moisture can also inhibit the development of color.

VEGETATIVE KEY TO THE RICCIACEAE OF MICHIGAN

1. Plants with large, easily visible (at $10\times$) ventral scales near the segment tips. Minute pores present in the dorsal epidermis. Strongly dimorphic (if terrestrial, sterile and convex on both surfaces; if aquatic, heart-shaped and flattened in cross section). Segments usually greater than 3.5 mm wide.
1. *Ricciocarpus natans* (fig. 1, a and b)
1. Plants with inconspicuous ventral scales and without epidermal pores, essentially monomorphic (terrestrial plants fertile or sterile, variously shaped in section) (Genus *Riccia*).
 2. Thalli solid, without conspicuous air chambers. Marginal cilia present or absent (Subgenus *Riccia*).
 3. Thallus margins lacking cilia. Plants green in shade to bright-red in sun forms. Cross section of thallus branch rectangular. Branches ca. 1 mm wide. Thallus surface appearing spongy.
2. *R. arvensis* (fig. 2,a)
 3. Thallus ciliate, with a gray-green color. Cross sections of branches oblique. Plants not appearing spongy.

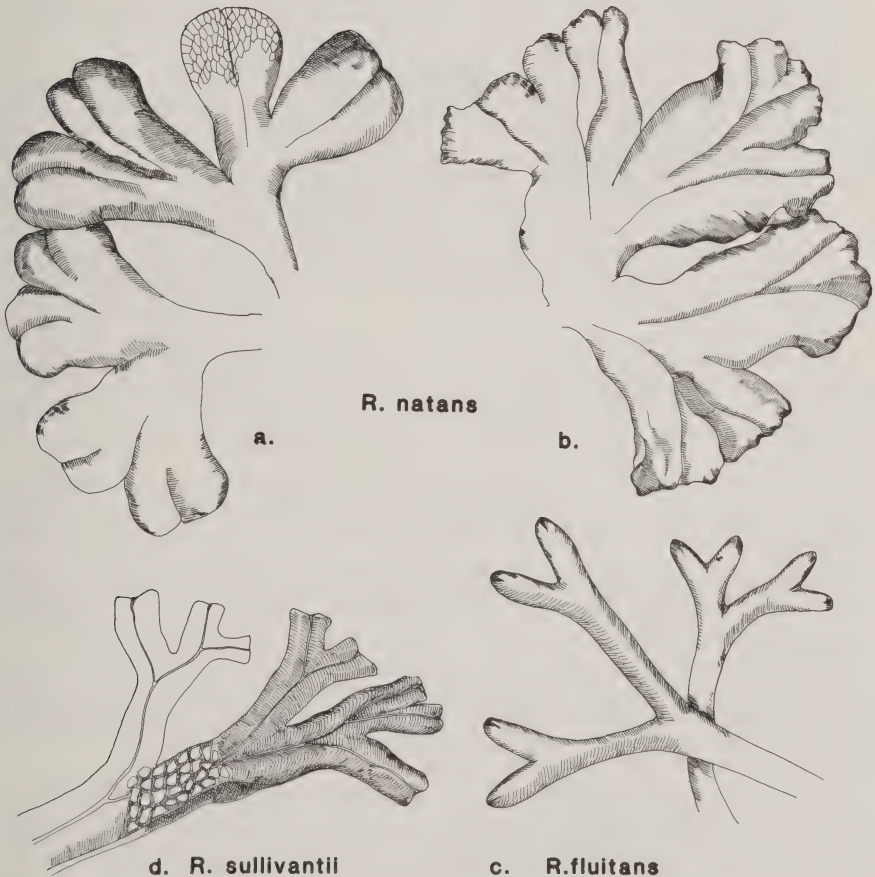


Fig. 1. Riccias. a,b. *Ricciocarpus natans* ($\times 12$). a, terrestrial form. b, aquatic form. c, *Riccia fluitans* ($\times 24$). d, *R. sullivantii* ($\times 24$).

4. Cilia present along the apical and lateral margins, especially prominent in drier habitats. Dorsal sulcus deep and wide. Branch segments ca. 2 mm wide.
3. *R. beyrichiana* (fig. 2,b)
4. Cilia present only at the tips of branches, short, and prominent only on the new growth. Dorsal sulcus shallow and narrow. Branch segments ca. 1 mm wide.
4. *R. hirta* (fig. 2,c)
2. Thalli with conspicuous air cavities, the internal photosynthetic tissue forming large air chambers. Marginal cilia absent (Subgenus *Ricciella*).
5. Thallus segments conspicuously thin and ribbon-like, mostly less than 1 mm wide.
6. Plants terrestrial, often fertile, little branched; branches thick and fleshy. Uncommon.
6. *R. canaliculata*
6. Plants aquatic or stranded, the terrestrial forms always sterile. Thallus narrow and repeatedly dichotomous. Common in ponds or slow-moving streams.
5. *R. fluitans* (fig. 1,c)
5. Thallus segments commonly more than 1 mm wide. Plants terrestrial.
7. Thallus segments 0.8–1.4 mm wide; plants bright but not crystalline green. Dorsal epidermis not lacunose.
7. *R. sullivantii* (fig. 1,d)
7. Thallus segments 1.5–2 mm wide; sun forms with clear, crystalline green pigmentation. Dorsal epidermis becoming prominently lacunose.
8. *R. crystallina* (fig. 2,d)
1. *Ricciocarpus natans* (L.) Corda
Plants aquatic or terrestrial, highly dimorphic. Aquatic forms occurring as heart-shaped rosettes, 5–9 mm. in diameter, over the surfaces of ponds and slow-moving streams. Ventral scales conspicuous, purplish. Narrower terrestrial forms more *Riccia*-like in appearance, rosettes 20–30 mm across with branches 2–3 mm wide. Branches thick and convex; obvious ventral scales lacking. In both forms, dorsal epidermis with distinct pores.
The large, purple-green terrestrial thalli and green, heart-shaped aquatic thalli, both bearing distinct pores in the dorsal epidermis, are not easily confused with others of the Ricciaceae.
Michigan: Monroe (81062a, 81076, 91087a, 81090a, 81091c) and Washtenaw Cos. (81072a). Indiana: Parker, 1938; Ohio: Miller, 1964; Ontario: Cain & Fulford, 1948; Wisconsin: Conklin, 1929; Minnesota: Schuster, 1953.
2. *Riccia arvensis* Aust.
Rosettes striking red and green, 10–20 mm across. With handlens, dorsal epidermis rough and appearing spongiöse but plants actually with compact photosynthetic tissue. Thallus branches 1.2–1.8 mm wide. Segment tips rounded to ovate. When dry, dorsal sulcus wide, shallow and prominent. Spores 70–90 μ m in diameter, the inner and outer faces equally areolate, the areolae 6–15 μ m wide.
Sun plants develop a strong, reddish color; otherwise, the thalli are greenish. The dorsal epidermis appears spongiöse; however, the epidermis is not truly lacunose, and the rounded tips further separate the species from *R. crystallina*. The plants seem associated with wetter sections of the habitat.
Michigan: Monroe (81061, 81078a, 81081a) and Wayne Co. (81069). Ontario: Cain & Fulford, 1948; Wisconsin: Conklin, 1929; Indiana: Parker, 1938.
3. *Riccia beyrichiana* Hampe
Rosettes incomplete, light-green, 15–35 mm across. Branches 1.5 mm wide, with a characteristically wide dorsal groove or sulcus and thick, convex margins. Stout marginal cilia numerous and prominent, less than 300 μ m long, present on all portions of the thallus. Spores 90–120 μ m in diameter, the inner faces mostly smooth but occasionally areolate, the outer faces strongly areolate with areolae about 15 μ m wide.
Riccia beyrichiana is readily identified by its light-green color, wide dorsal sulcus, prominently ciliate margins, and large size.
Michigan: Wayne (81067a) and Monroe Cos. (64025, 81064, 81080b, 81087b, 81089). Minnesota: Schuster, 1953; Wisconsin: Conklin, 1929.
4. *Riccia hirta* Aust.
Rosettes small to medium-sized, gray-green, highly branched, 10–20 mm. across. In older plants, the margins are tinged with purple. Branches ca. 1 mm wide, with narrow dorsal

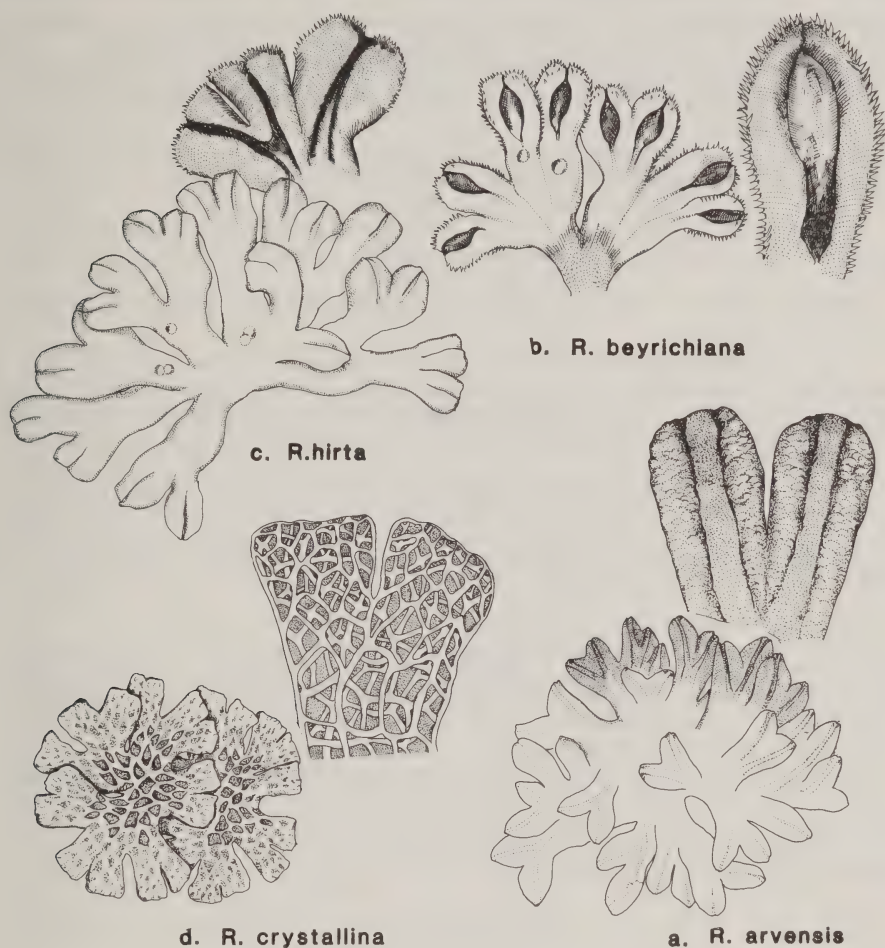


Fig. 2. Riccias. a, *Riccia arvensis*. b, *R. beyrichiana*. c, *R. hirta*. d, *R. crystallina* (all at $\times 12$).

sulcus. Young segments with small cilia at the squarrose tips, becoming deciduous with age or abraded by blowing sand particles. Spores 90–130 μm in diameter. Areolae of the inner face imperfectly developed, the outer face regularly areolate, with areolae 10–13 μm wide.

The purple-edged thallus margin is a good character of sun plants. The narrow, shallow dorsal sulcus distinguishes the plant from *R. beyrichiana*. Cilia may be overlooked. We did not notice them until the plants developed new growth in cultivation.

Michigan: Monroe (81060, 81063, 81077, 81080a, 81087d, 81090b, 81091b), Washenaw (81071), and Wayne Cos. (81067b); Minnesota: Schuster, 1953.

5. *Riccia fluitans* L.

Plants normally aquatic, sometimes stranded. Thalli light-green and regularly dichotomous. Branches 1–5 cm long and 0.5–0.9 mm wide; segments very shallowly grooved. Thalli truly areolate, the chambers visible through the epidermis. Plants never found fertile.

This common and cosmopolitan species is characterized by ribbon-like, light-green, dichotomous thalli. The plants may be found floating in ponds or slow moving streams. Branches of the stranded land form are often wider than those of the aquatic form but are never greater than 1 mm in width. Remarkably, the plants have never been found fertile. A fertile plant once

considered to be the land form of *R. fluitans* is now recognized as *R. canaliculata*. *R. fluitans* further differs from *R. canaliculata* in its thin, often branched, and areolate thallus.

Michigan: Numerous reports, see Steere, 1940; Indiana: Parker, 1938; Ohio: Miller, 1964; Ontario: Cain & Fulford, 1948; Wisconsin: Conklin, 1929; Minnesota: Schuster, 1953.

6. *Riccia canaliculata* Hoffm.

Rosettes small and little-branched. Branches thick and fleshy, 1.5–2.5 times wider than high. Plants always terrestrial and commonly fertile. Segments never wider than 1 mm; thalli not areolate. Branches lacking dorsal grooves. Spores 70–100 μ m wide.

This species differs from *R. fluitans* in its thick, little-branched thallus. It is solely a land plant and is commonly fertile. The very narrow branches separate this from other terrestrial Riccias.

Michigan: Wayne Co. (81068); there are no reports from states adjacent to Michigan.

7. *Riccia sullivantii* Aust.

Rosettes small, light-green, 10–18 mm across. Branches 1–1.5 mm wide, with subquadrate tips. Dorsal surface granular, becoming lacunose with age. Photosynthetic tissue areolate. Cross sections 2–3 times wider than high. Sporangia subglobose and rupturing ventrally. Spores 60–75 μ m in diameter, the wings 7–8 μ m across. Outer spore faces areolate, the areolae 8–11 μ m.

R. sullivantii is a delicate, pale-green plant. The segments are broader than in the *R. fluitans* complex. The regularly areolate spore patterns further separate this species from others in the subgenus *Ricciella*.

Michigan: Monroe (81087c, 81091g) and Washtenaw Cos. (81072d); Indiana: Parker, 1938; Ohio: Miller, 1964; Ontario: Cain & Fulford, 1948; Wisconsin, 1929.

8. *Riccia crystallina* L.

Thalli small to medium-sized, crystalline-green and lacking red or purple coloration. Tightly packed rosettes ca. 15 mm. in diameter. Branch segments 0.8–1.5 mm wide with subquadrate tips. Dorsal surface highly lacunose, resulting from a ruptured dorsal epidermis. Sporangia easily viewed through the reticulate tissue. Spores 67–84 μ m wide, wingless and areolate, the areolae ca. 10 μ m wide.

This species is highly distinct in the field because of its bright, clear-green color and highly lacunose dorsal surface giving the plants the appearance of shiny, emerald sponges. The plants were often associated with nitrogen-fixing legumes in moister locations.

Michigan: Monroe Co. (81062b, 81065b, 81078b, 81081b, 81091a); Minnesota: Schuster, 1953; Wisconsin: Schuster, 1953.

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THE VEGETATION OF THE MANISTEE NATIONAL FOREST, OCEANA AND MASON COUNTIES, MICHIGAN,

II. Checklist of Vascular Plants

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The first paper in this series summarized physical, historical, and ecological aspects of the Manistee National Forest study area (Mustard, 1983). This report presents a checklist of the flora, including 80 families, 234 genera, and 369 species. Of this number 314 species are native, 54 are introduced, and one is planted. No species listed by the Michigan DNR or the U.S. Fish & Wildlife Service as endangered, threatened, or rare were encountered.

According to Beaman (1970), 151 vascular plant families occur in Michigan; the study area has 53% of them. Over 10% of the vascular plant species of Michigan are found in this area. The largest families are Asteraceae (44 species), Poaceae (36 species), Cyperaceae (27 species), and Rosaceae (21 species). The largest genus, *Carex*, has 21 species. Five other genera have five or more species—*Viola* (7), *Solidago* (6), *Panicum* (6), *Polygonum* (6), and *Aster* (5).

Three grasses are especially noteworthy as range extensions. *Cynosurus echinatus* has been collected only once before in Michigan, near Kalamazoo (Stephenson, 1967). *Paspalum ciliatifolium* has not, to my knowledge, been collected north of Kent County; this collection extends the range approximately 100 km northward. *Agrostis hyemalis* var. *tenuis* f. *setigera* is well represented in Michigan's Upper Peninsula (Voss, 1972); it has previously been known only in Mecosta County in the northern Lower Peninsula.

All numbers cited represent Mustard collections deposited in MSC. Acronyms preceding the collection numbers are O, Oceana Co.; M, Mason Co. The systematic arrangement of families and sources of information follow Beaman (1970).

LYCOPODIACEAE

- Lycopodium clavatum* L. Running pine. O 834.
L. lucidulum Michx. Shining club-moss. O 717.

- L. obscurum*. Ground pine. O 322.
L. tristachyum Pursh. Ground pine. O 566, 816.

EQUISETACEAE

- Equisetum arvense* L. Field horsetail. O 636b.
E. hyemale L. Scouring-rush. O 636a.

- E. scirpoides* Michx. Dwarf horsetail. O 947, 1015.

OPHIOGLOSSACEAE

Botrychium multifidum (Gmel.) Rupr.
Leathery grape fern. O 891.

B. virginianum (L.) Sw. Rattlesnake fern.
O 452, 461.

OSMUNDACEAE

Osmunda cinnamomea L. Cinnamon fern.
O 463.

O. claytoniana L. Interrupted fern. O 316.
O. regalis L. Royal fern. O 522.

POLYPODIACEAE

Adiantum pedatum L. Maidenhair fern. O
315.

Athyrium filix-femina (L.) Roth. Lady fern.
O 405, 521.

Gymnocarpium dryopteris (L.) Newm.
Oak fern. O 468.

Matteuccia struthiopteris (L.) Todaro.
Ostrich fern. M 1003.

Onoclea sensibilis L. Sensitive fern. O
496.

Polystichum acrostichoides (Michx.)
Schott. Christmas fern. O 495.

Pteridium aquilinum (L.) Kuhn. Bracken
fern. O 474.

Thelypteris hexagonoptera (Michx.)
Weatherby Broad beech fern. O 529.

T. noveboracensis (L.) Nieuwl. New York
fern. O 383.

PINACEAE

Picea pungens Englem. Blue spruce. O
927.

Pinus resinosa Ait. Red pine. O 988.

P. strobus L. White pine. O 669.

Tsuga canadensis (L.) Carr. Eastern hem-
lock. O 515.

CUPRESSACEAE

Juniperus communis L. Common juniper.
O 819.

Thuja occidentalis L. White-cedar. O 527,
637.

LAURACEAE

Lindera benzoin (L.) Blume. Spice bush. O
952.

Sassafras albidum (Nutt.) Nees. Sassafras.
O 272, 670, 981.

ARISTOLOCHIACEAE

Asarum canadense L. Wild ginger. O 313.

NYMPHAEACEAE

Nuphar advena (Ait.) Ait. f. Yellow pond
lily. O 1038.

RANUNCULACEAE

Anemone canadensis L. Canada anemone.
M 996.

A. quinquefolia L. Wood anemone. O 360,
959.

Aquilegia canadensis L. Wild columbine.
O 382.

Caltha palustris L. Marsh marigold. O
237, 457, 944.

Clematis virginiana L. Virgin's-bower. O
711.

Coptis trifolia (L.) Salisb. Gold-thread. O
301.

Hepatica acutiloba DC. Liver-leaf. O 940,
945.

H. americana (DC.) Ker. Round-lobed
liver-leaf. O 903.

Ranunculus abortivus L. Kidney leaf-
buttercup. O 296.

R. recurvatus Poir. Hooked crowfoot. O
297.

R. septentrionalis Poir. Swamp buttercup.
O 289.

Thalictrum polygamum Muhl. Fall
meadow-rue. M 1001.

BERBERIDACEAE

Podophyllum peltatum L. May apple O
957.

MENISPERMACEAE

Menispermum canadense L. Canada moonseed. O 352; M 1002.

HAMAMELIDACEAE

Hamamelis virginiana L. Witch-hazel. O 374, 582, 823.

ULMACEAE

Ulmus americana L. American elm. O 458, 679.

URTICACEAE

Boehmeria cylindrica (L.) Sw. False nettle. M 738.

Laportea canadensis (L.) Wedd. Wood-nettle. O 506, 710.

Pilea pumila (L.) Gray. Clearweed. O 653.

Urtica dioica L. Nettle. M 739.

MYRICACEAE

Comptonia peregrina (L.) Coult. Sweet-fern. O 389, 986.

FAGACEAE

Fagus grandifolia Ehrh. American Beech. O 273, 393, 565.

Quercus alba L. White oak. O 783, 814.

Q. rubra L. Red oak. O 596, 597, 1023.

Q. rubra var. *borealis* (Michx. f.) Farw. Northern red oak. O 533, 1022.

Q. velutina Lam. Black oak. O 784, 872, 1202.

BETULACEAE

Alnus incana spp. *rugosa* (Du Roi) Clausen. Alder. O 734, 920.

Betula alleghaniensis Britt. Yellow birch. O 454.

B. papyrifera Marsh. White birch. O 953.

Carpinus caroliniana Walt. Muscle wood or blue beech. O 282, 347.

Ostrya virginiana (Mill.) K. Koch. Ironwood or hop hornbeam. O 317.

PHYTOLACCACEAE

Phytolacca americana L. Pokeweed. Sight record. (M).

CARYOPHYLLACEAE

Cerastium vulgatum L. Mouse-ear chickweed. O 306.

Dianthus armeria L. Deptford pink. O 483.

Lychnis alba Mill. White campion. O 440.

Saponaria officinalis L. Bouncing Bet. O 622.

Stellaria longifolia Muhl. Long-leaved stitchwort. O 399.

PORTULACACEAE

Claytonia virginica L. Spring beauty.¹ O 942.

CHENOPODIACEAE

Chenopodium album L. Lamb's quarters. O 674.

¹*C. caroliniana* Michx. (O 938) was discovered 5 km S of the *C. virginica* collection outside the study area. Voss (1968) reported mixed populations and possible hybrids of these taxa at Shelby, 19 km SW of the study area. Although no mixed populations were discovered, they are to be expected in the study area.

POLYGONACEAE

- Polygonum aviculare* L. Knotweed. O 858.
P. hydropiper L. Smart-weed. O 853.
P. hydropiperoides Michx. Water pepper.
 O 1195.
P. persicaria L. Lady's thumb. O 723.
P. punctatum Ell. Dotted smart-weed. M
 741.

- P. tenue* Michx. Slender knotweed. O 116.
Rumex acetosella L. Sheep sorrel. O 373;
 M 1055.
R. crispus L. Sour dock. O 365.
R. obtusifolius L. Bitter dock. O 493, 827.

HYPERICACEAE

- Hypericum boreale* (Britt.) Bickn. North-
 ern St. John's-wort. O 1189a.
H. canadense L. Canadian St. John's-wort.
 O 1189b.
H. perforatum L. St. John's-wort. O 570.

- H. punctatum* Lam. Spotted St. John's-
 wort. O 652.
Triadenum virginicum (L.) Raf. Marsh St.
 John's-wort. O 732.

TILIACEAE

- Tilia americana* L. Basswood. O 713; M
 1050.

MALVACEAE

- Malva moschata* L. Musk mallow. O 877.

VIOLACEAE

- Viola blanda* Willd. Sweet white violet. O
 958.
V. cucullata Ait. Marsh blue violet. O 295.
V. eriocarpa Schw. Yellow violet. O 293.
V. lanceolata L. Lance-leaved violet. O
 1013.

- V. pubescens* Ait. Yellow violet. O 983.
V. rostrata Pursh. Long-spurred violet. O
 967.

CISTACEAE

- Helianthemum canadense* (L.) Michx.
 Frostweed. O 394.

SALICACEAE

- Populus grandidentata* Michx. Big-tooth
 aspen. O 536, 1029.
P. tremuloides Michx. Trembling aspen. O
 534, 638, 890, 1031.

- Salix discolor* Muhl. Pussy willow. O 930,
 955.
S. humilis Marsh. Prairie willow. O 292.
S. petiolaris Sm. Slender willow. O 919.

BRASSICACEAE

- Arabidopsis thaliana* (L.) Heyn. Mouse-
 ear cress. O 978, 989.
Arabis drummondii Gray. Drummond's
 rock-cress. O 975, 1183.
Barbarea vulgaris R.Br. Yellow rocket. O
 298.
Betseroa incana (L.) DC. Hoary alyssum. O
 443, 476; M 998.

- Cardamine bulbosa* (Schreb.) BSP. Spring
 cress. O 278.
Dentaria diphylla Michx. Two-leaved
 toothwort.² O 307, 993.
Lepidium campestre (L.) R. Br. Field
 cress. O 348.
Rorippa islandica (Oeder) Borbas. Yellow
 cress. O 656.

²*Dentaria laciniata* Muhl. occurs 1 km SW of the study area in a beech-maple woodlot,
 Sect. 21, Crystal Twp., Oceana Co.

ERICACEAE

- Chimaphila umbellata* (L.) Bart. Pipsissewa or Prince's pine. O 568.
Epigaea repens L. Trailing arbutus. O 578, 921, 955.
Galtheria procumbens L. Wintergreen. O 594, 1210.
Monotropa hypopithys L. Pine-sap. O 471, 719, 776, 793, 1176.

PRIMULACEAE

- Lysimachia ciliata* L. Fringed loosestrife. O 700; M 742.
L. thyrsiflora L. Tufted loosestrife. O 1040.

GROSSULARIACEAE

- Ribes cynosbati* L. Prickly gooseberry. O 359.

SAXIFRAGACEAE

- Chrysosplenium americanum* Schw. Golden saxifrage. O 400.
Mitella diphylla L. Two-leaved bishop's cap. O 305, 381
M. nuda L. Bishop's cap. O 314, 379.

ROSACEAE

- Agrimonia gryposepala* Wallr. Agrimony. O 513, 519.
Amelanchier arborea (Michx. f.) Fern. June-berry. O 374, 616, 833, 976.
A. laevis Weig. June-berry. O 987.
A. sanguinea (Pursh) DC. Round-leaved June-berry. O 642.
A. spicata (Lam.) K. Koch. Low June-berry. O 956, 1032.
Crataegus mollis (T. & G.) Scheele. Hawthorn. O 283, 722.
Fragaria virginiana Duchesne. Wild strawberry. O 361, 966.
Geum allepicum Jacq. Avens. O 479.
G. canadense Jacq. White avens. O 488, 491, 600.
G. rivale L. Purple water avens. O 401.
Physocarpus opulifolius (L.) Maxim. Ninebark. O 743.

FABACEAE

- Amphicarpa bracteata* (L.) Fern. Hog peanut. O 708.
Desmodium nudiflorum (L.) DC. Naked stemmed beggar's tick. O 589, 790.
D. paniculatum (L.) DC. Panicked beggar's tick. O 590.

- M. uniflora* L. Indian pipe. O 581.
Pyrola virens Schweigg. Greenish-flowered wintergreen. O 1177.
Vaccinium angustifolium Ait. Blueberry. O 434, 577, 972.

- Trientalis borealis* Raf. Star-flower. O 311.

- Parnassia glauca* Raf. Grass-of-Parnassus. O 730.
Tiarella cordifolia L. Foam-flower. O 277, 369, 990.

- Potentilla argentea* L. Silvery cinquefoil. O 467, 1037.
P. recta L. Rough-fruited cinquefoil. O 477.
P. simplex Michx. Old-field cinquefoil. O 364.
Prunus serotina Ehrh. Black cherry. O 281, 508, 640.
Rosa blanda Ait. Meadow rose. O 402.
Rubus allegheniensis Porter. Blackberry. O 345, 573.
R. flagellaris L. Northern dewberry. O 1046.
R. pubescens Raf. Dwarf blackberry. O 310, 451.
R. strigosus Michx. Red raspberry. O 456, 512, 735.
Spiraea alba DuRoi. Meadow-sweet. O 736.

- Medicago lupulina* L. Black medick. O 403.
Melilotus alba Desr. White sweet-clover. O 812.
Trifolium hybridum L. Alsike clover. M 1054.

Lespedeza hirta (L.) Hornem. Hairy bush-clover. O 614, 788.
L. intermedia (Wats.) Britt. Bush-clover. O 659.

T. pratense L. Red clover. O 441.
Vicia cracca L. Blue vetch. O 469, 572, 703.

ONAGRACEAE

Circaea alpina L. Enchanter's nightshade. O 406.
Epilobium ciliatum Raf. Northern willow-herb. O 563, 695, 850; M 1214.

Oenothera biennis L. Evening-primrose. O 598.

CORNACEAE

Cornus alternifolia L.f. Alternate-leaved dogwood. O 370.
C. obliqua Raf. Narrowleaf dogwood. O 714.

C. rugosa Lam. Round-leaved dogwood. O 665.
C. stolonifera Michx. Red osier dogwood. O 929; M 1052.

AQUIFOLIACEAE

Ilex verticillata (L.) Gray. Black alder. O 505, 687.

EUPHORBIACEAE

Euphorbia maculata L. Milk purslane. O 1207.

RHAMNACEAE

Ceanothus americanus L. New Jersey tea. O 668, 1180.

VITACEAE

Parthenocissus quinquefolia (L.) Planch. Virginia creeper. O 509, 530.
Vitis aestivalis Michx. Summer grape. O 593, 784.

V. vulpina L. Sweet scented grape. M 1051.

ACERACEAE

Acer rubrum L. Red maple. O 466, 649, 926.
A. saccharinum L.f. Silver maple. O 629.

A. saccharum Marsh. Sugar maple. O 465, 588.
A. spicatum Lam. Mountain maple. O 321.

ANACARDIACEAE

Rhus copallina L. Dwarf black sumac. O 486.
R. typhina L. Staghorn sumac. O 680.

Toxicodendron radicans ssp. *negundo* (Greene) Gillis. Poison-ivy.³ O 696.

OXALIDACEAE

Oxalis stricta L. Wood-sorrel. O 475, 658.

GERANIACEAE

Geranium robertianum L. Herb-Robert. M 995.

³According to W. T. Gillis (pers. comm.), my specimen shows characteristics of the more northern *T. rydbergii* (Small ex Rydb.) Greene, indicating and exchange of genes between the two taxa in the tension zone of Michigan.

BALSAMINACEAE

Impatiens biflora Walt. Spotted touch-me-not. O 560.

POLYGALACEAE

Polygala paucifolia Willd. Fringed polygala. O 275.

ARALIACEAE

Aralia nudicaulis L. Wild sarsaparilla. O 319.

Panax trifolium L. Dwarf ginseng. O 274.

APIACEAE

Cicuta maculata L. Water-hemlock. M 740.

Cryptotaenia canadensis (L.) DC. Honewort. O 351, 489.

Daucus carota L. Wild carrot. O 558.

Pastinaca sativa L. Wild parsnip. O 1035.

Sanicula marilandica L. Black snake-root. O 376.

GENTIANACEAE

Gentiana andrewsii Griseb. Closed gentian. O 775.

APOCYNACEAE

Apocynum androsaemifolium L. Indian hemp. O 482.

ASCLEPIADACEAE

Asclepias incarnata L. Swamp milkweed. O 516, 702.

A. syriaca L. Common milkweed. O 725.

A. tuberosa L. Butterfly-weed. O 1179.

SOLANACEAE

Physalis heterophylla Nees. Ground-cherry. O 571.

Solanum carolinense L. Horse-nettle. O 747.

S. dulcamara L. Deadly nightshade. O 366, 497.

HYDROPHYLLACEAE

Hydrophyllum virginianum L. Virginia water-leaf. O 349.

BORAGINACEAE

Cynoglossum officinale L. Hound's-tongue. O 1014.

Echium vulgare L. Blueweed. O 1184.

VERBENACEAE

Verbena hastata L. Blue vervain. O 559.

V. urticifolia L. White vervain. O 748.

PHRYMACEAE

Phryma leptostachya L. Lopseed. O 609.

LAMIACEAE

Leonurus cardiaca L. Common motherwort. O 829.

Lycopus americanus Muhl. Cut-leaved water hoarhound. O 599.

L. uniflorus Michx. Northern bugle-weed. O 1188.

Monarda fistulosa L. Wild bergamot. O 1200.

M. punctata L. Horse-mint. O 569.

Prunella vulgaris (L.) Self-heal. O 487, 514, 654.

Satureja vulgaris (L.) Fritsch. Wild basil. O 481, 524, 557.

Mentha arvensis L. Field mint. O 602; M 1215.

M. piperita L. Peppermint. O 821.

Scutellaria lateriflora L. Mad-dog skull-cap. O 564.

PLANTAGINACEAE

Plantago lanceolata L. Rib grass. O 625.

OLEACEAE

Fraxinus americana L. White ash. O 444, 643, 697, 808, 954.

SCROPHULARIACEAE

Chelone glabra L. Turtlehead. O 631, 721.

Melampyrum lineare Desr. Cow-wheat. O 539.

Pedicularis canadensis L. Wood betony. O 438, 968.

Verbascum blattaria L. Moth mullein. O 1201.

V. thapsus L. Common mullein. O 1185.

Veronica americana (Raf.) Schw. American brooklime. O 409.

V. arvensis L. Corn speedwell. O 478, 979.

V. serpyllifolia L. Thyme-leaved speedwell. O 299.

OROBANCHACEAE

Conopholis americana (L.) Wallr. Squawroot. O 1021.

Epifagus virginiana (L.) Bart. Beech-drops. O 794, 795.

LENTIBULARIACEAE

Utricularia vulgaris L. Bladderwort. O 1045.

CAMPANULACEAE

Lobelia cardinalis L. Cardinal-flower. O 729.

L. kalmii L. Brook lobelia. O 733.

L. siphilitica L. Great blue lobelia. O 610, 852.

RUBIACEAE

Galium aparine L. Cleavers. O 350.

G. pilosum Ait. Hairy bedstraw. O 1178, 1181.

G. trifidum L. Small bedstraw. O 1043, 1194.

G. triflorum Michx. Sweet-scented bedstraw. O 372, 490, 634.

Mitchella repens L. Partridge-berry. O 424, 459.

CAPRIFOLIACEAE

Lonicera sp. O 464.

Sambucus canadensis L. Common elder. O 507.

Symphoricarpos albus (L.) Blake. Snow-berry. O 621.

Viburnum acerifolium L. Arrow-wood. O 537.

V. lentago L. Sheepberry. O 287, 626.

V. opulus var. *americanum* Ait. Highbush-cranberry. M 997.

ASTERACEAE

Achillea millefolium L. Common yarrow. O 511.

Ambrosia artemisiifolia L. Common ragweed. O 675, 811.

Antennaria neglecta var. *attenuata* (Fern.) Cronq. Pussy's toes. O 271, 974, 994.

Arctium minus Schk. Common burdock. O 709.

Artemisia campestris L. Wormwood. O 705, 818.

E. rugosum Houtt. White snakeroot. O 608.

Gnaphalium obtusifolium L. Sweet everlasting. O 682.

Helianthus divaricatus L. Woodland sunflower. O 619, 671.

Hieracium aurantiacum L. Devil's paintbrush. O 701.

H. pratense Tausch. Field hawkweed. O 354, 388, 718, 857.

- Aster laevis* L. Smooth aster. O 777.
A. lateriflorus (L.) Britt. Calico aster. O 632, 689.
A. puniceus L. Purple-stem aster. O 707, 826.
A. sagittifolius Willd. Arrow-leaved aster. O 780.
A. simplex Willd. Aster. O 693, 822.
Bidens cernua L. Stick-tight. O 706.
Centaurea maculosa Lam. Spotted star-thistle. O 613.
Chondrilla juncea L. Skeleton-weed. O 1212.
Chrysanthemum leucanthemum L. Ox-eye daisy. O 355, 1030.
Chichorium intybus L. Common chicory. O 1182.
Cirsium arvense (L.) Scop. Canada thistle. O 561.
C. vulgare (Savi) Tenore. Bull thistle. O 691.
Conyza canadensis (L.) Cronq. Horse-weed. O 1241.
Erigeron philadelphicus L. Fleabane daisy. O 480, 504, 657.
E. strigosus Muhl. Fleabane daisy. O 801, 810.
Eupatorium maculatum L. Spotted Joe-Pye weed. O 604, 712, 1206.
E. perfoliatum L. Boneset. O 603.

POTAMOGETONACEAE

- Potamogeton natans* L. Common pond-weed. O 1044.

JUNCACEAE

- Juncus brevicaudatus* (Engelm.) Fern. Narrow-panicked rush. O 1199.
J. effusus L. Common rush. O 543.

CYPERACEAE

- Carex annectens* (Bickn.) Bickn. Yellow-fruited sedge. O 518.
C. bromioides Willd. Brome-like sedge. O 291.
C. cephalophora Willd. Oval-headed sedge. O 358.
C. cristatella Britt. Crested sedge. O 520.
C. digitalis Willd. Slender wood sedge. O 580.
C. hystericina Willd. Porcupine sedge. O 407.
C. interior Bailey. Inland sedge. O 1041.
C. intumescens Rudge. Bladder sedge. O 854.
C. lasiocarpa Ehrh. Slender sedge. O 1011.

- Krigia virginica* (L.) Willd. Dwarf dandelion. O 395, 1028.
Lactuca biennis (Moench) Fern. Wild lettuce. O 690.
L. canadensis L. Wild lettuce. O 620.
Matricaria matricarioides (Less.) Porter. Pineapple-weed. O 446.
Prenanthes alba L. Rattlesnake-root. O 831.
P. altissima L. Rattlesnake-root. O 778.
Rudbeckia hirta L. Black-eyed Susan. O 746.
R. laciniata L. Coneflower. O 607.
Senecio aureus L. Golden ragwort. O 380.
Solidago caesia L. Blue-stem goldenrod. O 792.
S. canadensis L. Canada goldenrod. O 676.
S. flexicaulis L. Broad-leaved goldenrod. O 611.
S. graminifolia (L.) Salisb. Grass-leaved goldenrod. O 627, 699.
S. puberula Nutt. Downy goldenrod. O 684.
S. rugosa Mill. Wrinkle-leaved goldenrod. O 686, 698.
Taraxacum officinale Weber. Dandelion. O 828, 969.
Tragopogon major Jacq. Yellow goat's beard. O 439.

- J. tenuis* Willd. Path rush. O 661, 745, 1186.

- C. pensylvanica* Lam. Pennsylvania sedge. O 922, 984.
C. plantaginea Lam. Plantain-leaved sedge. O 950.
C. rosea Willd. Stellate sedge. O 356.
C. rugosperma Mack. O 398.
C. scoparia Willd. Pointed broom sedge. O 1190; M 1217.
C. stipata Willd. Awl-fruited sedge. O 290, 346.
C. vulpinoidea Michx. Fox sedge. O 1216.
Cyperus filiculmis Vahl. Slender cyperus. O 1187.
C. schweinitzii Torr. Schweinitz's cyperus. O 809.
Dulichium arundinaceum (L.) Britt. Three-way sedge. O 1039, 1196.

- C. laxiflora* Lam. Loose-flowered sedge. O 357.
C. leptonervia Fern. O 303.
C. lupulina Willd. Hop sedge. O 377; M 999.
C. muhlenbergii Willd. Muhlenberg's sedge. O 1027.
C. ormostachya Wieg. O 494.

POACEAE

- Agropyron repens* (L.) Beauv. Quack grass. O 673, 803.
A. trachycaulum (Link) Malte. Wheat grass. O 787, 1175.
Agrostis gigantea Roth. Redtop. O 540, 651, 683.
A. hyemalis (Walt.) BSP. var. *hyemalis*. Ticklegrass. O 799.
A. hyemalis var. *tenuis* f. *setigera* (Fern.) E. Voss. Ticklegrass. O 1192.
A. tenuis Sibth. O 804.
Andropogon scoparius Michx. Little bluestem. O 704, 817.
A. virginicus L. Broom-sedge. O 53, 813.
Aristida basiramea Vasey. Three-awned grass. O 797.
Bromus inermis Leyss. Smooth brome. O 806.
Cenchrus longispinus (Hackel) Fern. Sandbur. O 1218.
Cinna arundinacea L. Wood reed grass. O 824.
Cynosurus echinatus L. Dogtail. O 442.
Dactylis glomerata L. Orchard grass. O 390.
Danthonia spicata (L.) R. & S. Poverty grass. O 646, 895.
Elymus virginicus L. Wild-rye. O 737.
Eragrostis cilianensis (All.) Mosher. Stink grass. O 624, 1208.
E. spectabilis (Pursh) Steudel. Tumble grass. O 681.
Glyceria canadensis (Michx.) Trin. Rattlesnake grass. O 1197.

SPARGANIACEAE

- Sparganium chlorocarpum* Rydb. Burreed. O 1198.

TYPHACEAE

- Typha latifolia* L. Common cat-tail. O 830.

ARACEAE

- Arisaema triphyllum* (L.) Schott. Jack-in-the-pulpit. O 309.

- Eleocharis smallii* Britt. Small's spike-rush. O 1012, 1193.
Scirpus atrovirens Willd. Bulrush. O 485, 542.
S. cyperinus (L.) Kunth. Wool-grass. Sight record. (O).

- G. grandis* S. Wats. Manna grass. O 54.
G. striata (Lam.) Hitchc. Fowl manna grass. O 371, 523, 688.
Leersia oryzoides (L.) Swartz. Cut grass. O 562.
Leptoloma cognatum (Schult.) Chase. Diffuse crab-grass. O 574, 802.
Muhlenbergia frondosa (Poiret) Fern. O 832.
M. mexicana (L.) Trin. Satin-grass. O 650.
M. schreberi J. F. Gmelin. Nimblewill. O 655.
Oryzopsis asperifolia Michx. White-grained mountain-grass. O 971, 982.
Panicum columbianum Scribner. Panic grass. O 387, 428.
P. dichotomum L. Forked panic-grass. O 426, 644, 800, 1209.
P. implicatum Britt. Slender-stemmed panic-grass. O 1191.
P. latifolium L. Broad-leaved panic-grass. O 425, 667.
P. linearifolium var. *wernerii* (Britt.) Fern. White-haired panic-grass. O 1025.
Paspalum ciliatifolium var. *stramineum* (Nash) Fern. O 805.
Phalaris arundinacea L. Reed canary grass. O 820, 1036.
Poa compressa L. Canada bluegrass. O 397, 789, 798.
P. pratensis L. Kentucky bluegrass. O 392, 970.
Sporobolus cryptandrus (Torr.) Gray. Dropseed. O 859.

- Calla palustris* Wild calla. O 1042.

LEMNACEAE

Lemna minor L. Duckweed. O 924.

LILIACEAE

Asparagus officinalis L. Garden asparagus. O 1018.

Clintonia borealis (Ait.) Raf. Yellow beadlily. O 135.

Erythronium americanum Ker. Adder's tongue. O 327, 928.

Lilium michiganense Farw. Michigan lily. O 728.

Maianthemum canadense Desf. Wild lily-of-the-valley. O 300.

Medeola virginiana L. Indian cucumber-root. O 384.

Polygonatum pubescens (Willd.) Pursh. Solomon-seal. O 302.

Smilacina racemosa (L.) Desf. False Solomon-seal. O 302.

Trillium grandiflorum (Michx.) Salisb. Common trillium. O 308, 932.

Uvularia grandiflora Sm. Bellwort. O 937, 992.

IRIDACEAE

Iris versicolor L. Wild blue flag. M 1000.

ORCHIDACEAE

Corallorhiza maculata Raf. Spotted coral-root. O 662.

C. odontorhiza (Willd.) Nutt. Fall coral-root. O 744, 770, 791.

Cypripedium acaule Ait. Pink lady-slipper. O 567.

C. calceolus var. *pubescens* (Willd.) Correll. Yellow lady-slipper. O 1005.

Goodyera pubescens (Willd.) R. Br. Rattlesnake plantain. O 606, 1006.

Habenaria hyperborea (L.) R. Br. Tall northern bog orchid. O 615.

H. lacera (Michx.) Lodd. Ragged fringed orchid. Sight record. (O).

H. psychodes (L.) Spreng. Purple fringed orchid. O 601, 633.

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CAREX FORMOSA IN NORTH DAKOTA

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While examining specimens from North Dakota, I was surprised to find that two originally reported as *Carex gracillima* Schwein. and later as *C. davisii* Schwein. & Torr. are actually *C. formosa* Dewey. The result is a range extension of *C. formosa* and a removal of *C. davisii* from the North Dakota flora.

Stevens (1950) reported *C. gracillima* from North Dakota on the basis of Stevens 831 and 832 collected in a wooded area along the Sheyenne River, Richland Co., near Leonard, July 1945). Later (1972), based on annotations by O. A. Kolstad, he reported them as *C. davisii*. More recently, apparently based on the latter report, *C. davisii* as again recorded from North Dakota by McGregor *et al.* (1977); *C. formosa* was not reported for the area covered by the McGregor *et al.* atlas.

Although the specimens superficially resemble *C. davisii* in having pubescent leaves (with pubescence mostly confined to the underside), strongly reddened basal sheaths, and gynaeandrous terminal spikes, these characteristics are also found in *C. formosa*. On close examination, each plant is found to have staminal filaments in at least the lowest scale on each lateral spike, pistillate scales that are acute to short-cuspidate and much shorter than the perigynia, and perigynia that possess only two strong nerves, the others being quite obscure. Based on these characters, all used by Mackenzie (1931–35) and others to separate *C. formosa* from *C. davisii*, Stevens 831 and 832 should be assigned to *C. formosa*. In *C. davisii*, the lateral spikes are entirely pistillate, the pistillate scales are acuminate and usually much longer than the perigynia, and the perigynia have several (usually more than 10) strong nerves.

Although Mackenzie reported *C. formosa* only as far west as Wisconsin, Fernald (1950) reported it from Minnesota and northeastern Iowa. In Minnesota, it is known only from Ramsey Co. in the east-central portion of the state, where it is very uncommon in dry deciduous woods. The North Dakota site, about 250 miles northwest of the Minnesota localities, represents the westernmost known station for *C. formosa*.

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FLORAL ECOLOGY OF WITCH-HAZEL
(HAMAMELIS VIRGINIANA), //

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A notable feature of witch-hazel (*Hamamelis virginiana*), a common shrub of eastern deciduous forests, is its late-autumn flowering. In Michigan, it is probably one of the last species to initiate flowering, and it may retain flowers well after the first frosts. This unusual phenology captured the interest of early workers concerned with pollinator availability for a species flowering under unfavorable weather conditions (Meehan 1890; Graenicher 1906); they observed insects at witch-hazel flowers on some occasions but a conspicuous lack of visitors on others. Aside from these early observations, almost no information exists on witch-hazel floral biology.

I report here observations on several aspects of reproductive ecology, including floral persistence, flowering period, breeding system, and insect visitation. While these data identify, at the floral level, a suite of characteristics that influence pollination, the overall consequences of this shrub's phenology must be assessed in terms of the reproductive performance of individuals in the population. Therefore, I also examined the reproductive behavior of individual plants as reflected by the distribution of flower production and fruit set success within and among years. Observations were made from 1977 to 1980 at the George Reserve, a large mixed tract of oak-hickory forests, old fields, and marshes in Livingston Co., Michigan.

Witch-hazel ranges from Nova Scotia to Wisconsin and south to northern Florida and eastern Texas (Sargent 1905; Wood 1974). It has a limited capacity to sprout by suckering, but the multiple-stemmed individuals are generally distinct from each other. Over its range, the shrub flowers from September to December (Jenne 1966). The fragrant flowers occur in axillary inflorescences with usually three flowers per inflorescence. A four-lobed campanulate calyx forms a receptacle inside which four bright yellow, strap-like petals are inserted. The petals alternate with four functional stamens which in turn alternate with four reduced staminodes secreting small amounts of nectar. The half-inferior ovary is bicarpellate and bilocular, with one functional ovule per locule; possibly a second ovule aborts very early in development (cf. Shoemaker 1905). While pollen transfer and pollen tube growth take place during flowering in autumn, fertilization does not occur until the following spring, five to seven months after pollination, due to dormancies in both ovules and pollen tubes (Shoemaker 1905, Flint 1957). Fruits develop over the growing season, and ripe seeds are dispersed in late

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autumn, simultaneous with flowering of the next year's potential seed crop. Dispersal occurs by mechanical expulsion of seeds from the loculicidally dehiscent woody fruit capsule.

To measure flower persistence, a series of inflorescences was individually tagged just before anthesis in fall 1977 and checked every two to four days for flower opening, anther dehiscence, and the beginning of flower withering. Incidental observations were made on insect visitors through the flowering season of 1978. Insects were systematically collected from flowers when encountered in the course of other work during the peak flowering month of October and were also collected or recorded from seven half-hour observation periods spread out over this month.

Several experiments used to investigate the breeding system were made difficult by the small size of flowers and the five to seven month delay between pollination and fertilization. In 1977, on each of five plants, groups of five inflorescences were tagged and subjected to one of four treatments: control (open to normal pollination); emasculation (anthers excised prior to anthesis); isolation (enclosed in bags throughout anthesis); and isolation and emasculation (anthers excised and inflorescences bagged). Fertilization success was recorded for all treatments in the following spring. In 1979, I selected branches with a number of inflorescences and enclosed them prior to anthesis inside doubled bags made of fine mosquito netting. When anthesis began, all flowers in a single bag were subjected to one of three treatments: cross-pollination (anthers excised and flowers hand-pollinated with pollen from a distant source); self-pollination (flowers hand-pollinated with their own pollen); and isolation (no manipulation). Hand-pollinations were performed only once per flower, and the bags were replaced after manipulation until all flowering activity in the shrub population had ceased. The bags were then removed so as not to interfere with the flowers through the winter, and fertilization success was recorded the following spring.

In each of four 20 × 20 m plots, located in different areas of the George Reserve, a random sample of 20 plants in flower was selected in fall 1977 for monitoring flower production and fruit set. In each flowering season from 1977 to 1979, the total number of inflorescences was counted directly on each plant. A sample of inflorescences was selected at random to estimate the mean number of flowers per inflorescence. In each spring following the fall flowering, the total number of inflorescences with successful fruit set (irrespective of the number set) was counted on each plant, and a sample of infructescences provided an estimate of the mean number of fruits set per inflorescence. The same plants were used over the 3-year period. In 1978, the basal area of all stems ≥ 1 cm in diameter was measured for each plant as a reflection of overall relative shrub size.

Floral Phenology

Flowering spanned the period from late September to mid-November. Individuals were relatively synchronized in flowering, and for a subset of 44 individuals for which I made weekly phenological observations from the beginning of October to late November, 32 had flowering periods of at least four weeks, and nine of these flowered over a 5-week period ending in mid-November.

Persistence of single flowers averaged 14 days (s.d. 3, $n = 84$), from the time of opening to the beginning of flower withering. The mean number of days to anther dehiscence after floral opening was 3.4 (s.d. 2, $n = 119$). Meehan (1890) recorded this interval as one day and thought that the stigmas became receptive simultaneously, but Graenicher (1906) called the flowers protogynous, with stigma receptive the first day and anthers dehiscing the second. No tests of stigma receptivity were performed. If anther dehiscence and stigma receptivity occur early in anthesis, flowers may not be sexually

functional during the entire time span of anthesis but may serve an attractive function or act as pollen donors.

Pollination System

Conspicuous floral display, fragrant flowers, nectar production, and adherent pollen not easily dislodged by wind all suggest an entomophilous pollination syndrome (Faegri & van der Pijl 1971). However, the relatively open flower structure suggests no specialized adaptation to admit only one type of pollinator. While the flowers measure 2.5–3 cm across due to the long petals, the calyx cup measures only 4–5 mm in diameter, and the stamens are not prominently exerted. A small insect probing or creeping down to the nectaries would likely contact open anther valves on either side and thus pick up pollen and transfer it to other stigmas simply by moving over the flowers. In contrast, larger insects would be less likely to contact anthers or stigmas in this manner and thus be less effective as pollinators.

A list of potential insect pollinators observed at flowers confirms the expectation that the visitor assemblage is diverse (Table 1), as other workers have found (Graenicher 1906, Jenne 1966). The Diptera and Hymenoptera were most prominent. Some Hemiptera and Homoptera were seen, but as these are sap-feeding rather than nectar- or pollen-feeding, they are unlikely to act as pollen vectors. A large number of the visitors were small gnats (Diptera: Nematocera) and small parasitoid wasps whose size would allow them complete access to both pollen and stigmas; many did have pollen on

TABLE 1. Families of insect visitors observed on witch-hazel flowers in 1978.

	No. individuals (no. with pollen)		No. individuals (no. with pollen)
Coleoptera		Diptera (cont.)	
Bruchidae	1	Brachycera	
Byrrhidae	1	Tachinidae	2 (2)
Chrysomelidae	5 (3)	Cyclorrhapha	
Lampyridae	1	Calliphoridae	1
Lepidoptera		Chloropidae	1 (1)
unidentified	1	Syrphidae	2 (1)
Diptera		Hymenoptera	
Nematocera		Braconidae	1 (1)
Cecidomyiidae	7 (1)	Eulophidae	1 (1)
Chironomidae	2 (2)	Formicidae	2 (2)
Culicidae	1	Halictidae	2 (2)
Psychodidae	1	Platygasteridae	1 (1)
Scatopsidae	1 (1)	Proctotrupidae	1 (1)
Sciaridae ¹	32 (20)	Pteromalidae	1
Tipulidae	1 (1)	Vespidae	1 (1)

¹all *Bradysia* sp.

their bodies (Table 1). In particular, a small fungus gnat (*Bradysia* sp.) was the most common and most consistently observed insect over the entire flowering period. Even after other insects disappear in late autumn, this fly appears to have bursts of flight activity whenever warm temperatures occur and may thus be an important pollen vector.

Conditions favoring insect pollinator activity, while unpredictable, do occur during the flowering period. In the study area, 50% (s.d. 4, $n = 3$ yr) of the days between mid-September and mid-November had daily maximum temperatures greater than 15°C (59°) (unpubl. George Reserve records), an approximate flight activity threshold for some insects (cf. Taylor 1963). Insect activity at flowers was generally higher and the assemblage more diverse on warm days than on cold days. Witch-hazel may thus be termed opportunistic in its use of whatever insects are active in the fall, and its long flowering period allows opportunities to take advantage of favorable conditions when they occur.

Breeding System

The breeding system is characterized by self-compatibility and autogamy (self-pollination without external agents). In the first pollination experiment, the percentages of inflorescences with some fruit set were control, 6% ($n = 16$); emasculated, 4.5% ($n = 22$); isolated, 19% ($n = 26$); and isolated and emasculated, 0% ($n = 21$). The success of control and outcrossed flowers was similar. No apomixis occurred, but an interesting result is that the rate of selfing (isolate group) was higher than for control flowers open to normal pollination (including self-pollination). The results of the more extensive 1979 experiments were also unusual (Table 2). The highest fruit set success occurred in the group that had been isolated with no manipulation. The poor success of the artificially cross-pollinated flowers suggests that manipulation (especially anther excision) may traumatize flowers and interrupt normal fertilization, while the lower success of the hand-pollinated treatments in general may reflect failure to introduce pollen when stigmas were most receptive. However, the high success of the bagged, unmanipulated flowers is surprising, since in the shrub population as a whole, levels of fruit set were often lower (see below).

TABLE 2. Pollination success of experimentally cross- and self-pollinated witch-hazel flowers in 1979.

	% of inflorescences with some fruit set (n)
Hand-pollinated	
outcrossed	3 (58)
selfed	26 (61)
Isolated (no manipulation)	43 (77)

The possibility of a strongly inbred system merits further investigation; the capacity for selfing frees the shrub from complete reliance on an unpredictable pollinator community.

Flower Production and Fruit Set

The distribution of individual flower production is variable and highly skewed in any given year, with only a few plants having very large flower crops (Fig. 2). This distribution directly reflects the size (and probably age) structure of the witch-hazel population, as stem basal area and inflorescence production in 1978 were highly correlated ($r=0.75$, $n=70$, $P<.01$). Individuals do not necessarily flower every year. Of the plants that flowered in 1977, four produced no flowers in 1978, nine individuals failed to flower in 1979, and one produced no flowers in 1978 or 1979 (Fig. 2). These failures



Fig. 1. Flowers of *Hamamelis virginiana*.

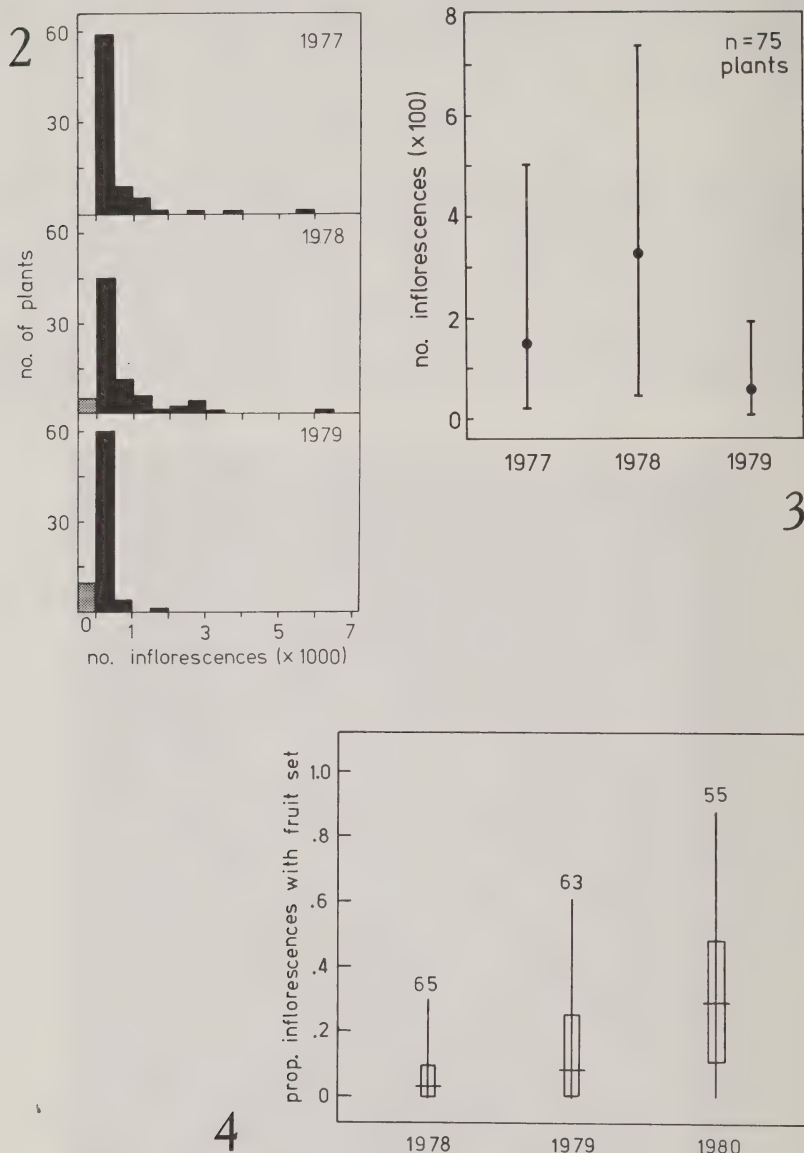


Fig. 2. Distribution of floral production for 80 individuals over a 3-year period. Stippled area represents plants that initiated no new flowers subsequent to 1977. No. of inflorescences $\times 3$ = total flower production. Fig. 3. Annual variation in average inflorescence production over a 3-year period. Closed circles are medians, and lines are the interval from 25th to 75th percentile. Fig. 4. Annual variation in proportion of inflorescences with successful fruit set. Year follows year of flowering (cf. Fig. 3). Horizontal line is the median; rectangles are interval from 25th to 75th percentile, and vertical lines the range. Numbers are sample size (numbers of plants).

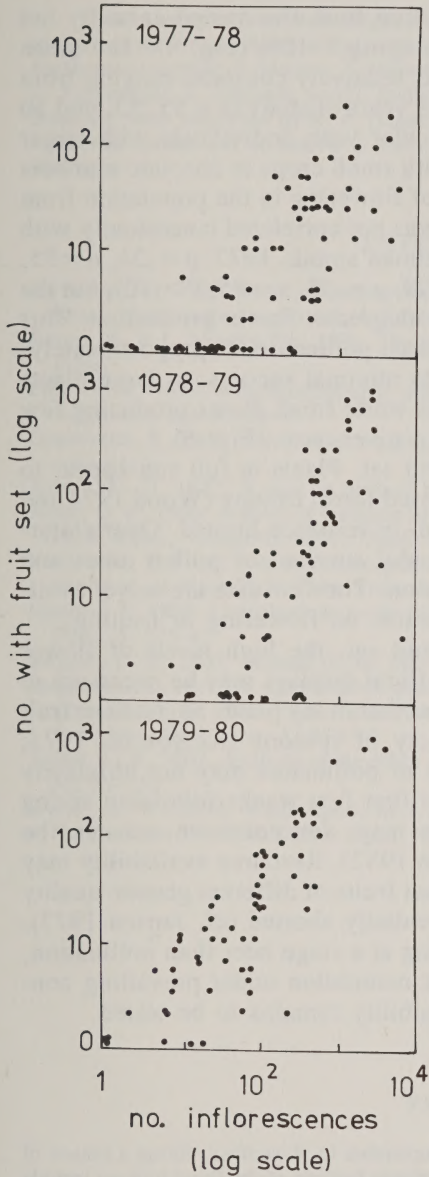


Fig. 5. Variation in fruit set as a function of flower crop size over a 3-year period. First year in pair is for flowering, and the second is for fruit set (e.g. 1977-78).

resulted from a complete absence of floral bud initiation rather than a mere failure of buds to open. Generally, plants that skipped years had small flower crops (<100 inflorescences) previously (3 of 4 in 1978 and 5 of 9 in 1979). Flower production also varied in magnitude for all individuals from year to year (Fig. 3). More flowers were produced in 1979 than in the other two years.

The proportion of inflorescences setting fruit also varied annually but was generally low in the population, averaging 5–10% (Fig. 4). The mean number of fruits set per inflorescence was relatively constant, ranging from 2.5–2.7 (out of a possible 3) over the three years of study ($n = 55, 53$, and 50 for 1978–80, respectively). In any particular year, individuals with larger flower crops set more fruits than those with small crops in absolute numbers (Fig. 5), regardless of the average level of flowering in the population from year to year. However, percent fruit set was not correlated consistently with individual inflorescence production (Spearman's rank, 1977: $p = .24$, $n = 55$, $P = .05$; 1978: $p = .42$, $n = 60$, $P < .01$; 1979: $p = .08$, $n = 55$, $P > .10$), but the trend was for increasing percentage set with greater flower production. This suggests that large floral displays may attract pollinators disproportionately. Size of floral display may be important to minimal success, as large plants with many flowers always bear some fruit while small plants producing few flowers may not necessarily set fruit in a given year (Fig. 5).

Other factors may also influence fruit set. Plants in full sun appear to bear larger fruit crops than those under closed forest canopy (Wood 1974 and pers. obs.), and thus fruit set may be light- or resource-limited. Overwintering temperatures may also affect successful survival of pollen tubes and ovules and thus influence spring fertilization. Too few data are as yet available to evaluate the effect of weather factors on flowering or fruiting.

Given the relatively low average fruit set, the high levels of flower production may seem wasteful, but large floral displays may be necessary to attract pollinators. However, it is also clear that many plants adjust their fruit crop sizes after pollination, for a variety of reasons (Kozlowski 1973; Stephenson 1981). Thus, the availability of pollinators may not ultimately limit witch-hazel fruit production. In the first few weeks following spring fertilization, 40–60% of initiated fruits may, for unknown reasons, be aborted and shed by the plants (De Steven 1982). Resource availability may be implicated, but another possibility is that fruits of different genetic quality (perhaps those that are selfed) are preferentially aborted (cf. Janzen 1977). This could control the degree of inbreeding at a stage later than pollination, according to resources available for fruit maturation under prevailing conditions of the growing season. This possibility remains to be tested.

SUMMARY

In Michigan, witch-hazel flowers from late September to November, during a season of weather unreliable for insect pollinator activity. Pertinent features of the floral biology include fertilization delayed until the spring following pollination and a breeding system with some autogamy. Insect visitors are diverse and limited to occasional periods of warm weather. The capacity for selfing frees witch-hazel from complete dependence on an unreliable pollinator community. A variable individual floral production reflects the size structure of the population. Plants with low floral production do not consistently set fruit every year, and thus large floral displays may enhance pollinator attraction. Average floral production by the population also varies from year to year, as do levels of pollination success. Overall, fertilization success is generally low (averaging 5–10%). However, pollination may not ultimately limit fruit production, since substantial numbers of growing fruits are aborted after fertilization.

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On the cover:
A hybridizing community of *Typha*
in Genesee County, Michigan;
photo by Joe P. Smigiel